PROCEEDINGS

OF

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

PITTSBURG, PA.

VOL. VI.

1890.

CONTENTS.

OFFICERS FOR 1890.

PRESIDENT,

W. L. Scaife.

VICE-PRESIDENTS,

Two Years—Phineas Barnes. One Year—A. E. Hunt.

DIRECTORS,

Two Years—R. N. Clark. Two Years—W. G. Wilkins.

One Year—William Metcalf. One Year—M. J. Becker.

SECRETARY,

One Year—S. M. Wickersham.

TREASURER,

One Year—A. E. Frost.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

This Society does not hold itself responsible for the opinions of its members.

TENTH ANNUAL MEETING.

PITTSBURG, JANUARY 21ST, 1890.

SOCIETY met at 8 o'clock P.M., President Brashear in the chair.

Vice-Presidents W. L. Scaife and A. E. Hunt, Director Charles Davis, and 60 members and 4 visitors were present.

The Board presented the names of the following gentlemen, applicants for membership: John M. Goodwin, William Whigham, H. Saunders Morris, L. B. Stillwell, and F. S. Smith, who were balloted for and elected.

The Committee on Union of Societies in the occupancy of one building, presented a printed report, which was distributed.

A. E. Hunt offered the following resolution:

"That the report of the Committee on the union of the various Societies be received, and Resolved, that this Society is ready to join with other Societies in occupying a common home, under suitable conditions, when offered by the Pittsburg Academy of Science and Art," which was adopted.

A. E. Frost presented the following report:

REPORT OF TREASURER

For the Year Ending January 21st, 1890.

RECEIPTS.

1889. January 20.

Balance,					$ 50.24	
Dues from	1	member to	Jan.,	1885,	5.00	
"	3	"	"	1886,	15.00	
"	6	"	"	1887,	30.00	
"	14	"	"	1888,	70.00	
"	41	"	"	1889,	205.00	
"	270	"	"	1890,	1350.00	
"	1	"	"	1891,	2.50	
Total,						$1727.74

Expenditures.

Printing,	$336.50	
Rent of Rooms,	268.00	
Salary of Secretary,	200.00	
Postage and Office Expenses,	154.99	
Insurance,	91.20	
Periodicals,	155.39	
Binding,	66.35	
Stenographer,	50.00	
Book Cases,	57.25	
Commissions on Collections,	53.38	
Blackboard,	14.20	
Total,		$1447.26
Balance in hands of Treasurer,		280.48
		$1727.74

Respectfully submitted,

A. E. Frost,
Treasurer.

The report of S. M. Wickersham, Secretary, was read by J. A. Brashear, viz.:

TENTH ANNUAL REPORT

OF THE

Secretary of the Engineers' Society of Western Pennsylvania.

Pittsburg, January 21, 1890.

On the 22d January, 1889, the number of names on our list of members was		342
At that meeting were dropped from the roll		13
Leaving on the active list		329
During the year there were admitted		24
Aggregating		353
In the same time we lost by death	3	
" " " by resignation	14	
		17
Leaving on the rolls		336

Ten regular meetings were held and 11 papers were read, viz.:

January 22d. The ninth annual meeting. President Dempster read his retiring address.

February 19th. J. W. Langley read a paper on "International Analysis of Iron and Steel." H. D. Hibbard read a paper on "Electric Welding of Metals."

March 19th. T. H. Johnson read a report from the Committee on Roads, together with the draft of an act for the construction and care of roads, to be presented to the State Legislature for action. J. A. Brashear read a paper on "The Manufacture of Optical Glass."

April 16th. A. E. Hunt read a paper on "The Testing of Metals and Testing Machinery."

May 21st. Louis I. Clark gave a talk on "The Phonograph and Graphophone."

June 18th. Thos. P. Roberts addressed the meeting on the "Johnstown Disaster and South Fork Dam."

October 15th. Isaac S. McGiehan gave a discussion on "Standard Metal Ties."

November 19th. Arthur Kirk read a paper on the "Use of Dynamite in Breaking the Jam at Johnstown."

December 17th. A paper prepared by Alfred E. Hunt on "The Stone Used for Structural purposes in Allegheny County," was read by G. H. Clapp.

The ten meetings were attended by 398 members and visitors, being an average of 39.8 to each. Number of visitors making use of the library was 1067.

S. M. Wickersham,
Secretary.

F. C. Phillips reported for Committee on Library:

January 22, 1890.

President Eng. Soc. W. Pa.:

Sir: The past year has been an uneventful one so far as improvements in the library are concerned.

The number of books added to the collection since the last annual meeting is 67. During the year 1889 the Librarian's

record shows that there were 1067 visitors to the library, an increase of 301 over the number for 1888.

It has been the aim of the committee to have all journals bound as soon as each volume is complete. As is well known the use of the rooms is not confined to members, non-members being permitted to consult the books. We have to report a constantly increasing demand for the literature of electricity and we believe that an urgent demand exists for additional works in this department. A request was made a year ago that members should notify the committee of the names of works relating to special branches of engineering or research, which in their opinion should be in the library. For the benefit of the incoming committee, it is suggested that this request be borne in mind.

Respectfully submitted,
F. C. PHILLIPS,
CHARLES DAVIS,
GEO. S. DAVISON.

The election of officers for the ensuing year being in order, C. H. Davis moved that the Secretary cast a ballot for the ticket recommended by the Nominating Committee at the December meeting, which motion was unanimously adopted. The ballot was cast by B. Spear, Secretary *pro tem*, and the following officers elected:

W. L. Scaife, President, one year; P. Barnes, Vice-President, two years; R. N. Clark, Director, two years; W. G. Wilkins, Director, two years; S. M. Wickersham, Secretary, one year; A. E. Frost, Treasurer, one year; after which J. A. Brashear read the following paper:

THE REFINEMENTS OF MODERN MEASUREMENTS AND MANIPULATIONS.

Progress is to-day written upon every page of the world's record; and particularly in the realms of science is it making its unmistakable mark; from thence extending outward to the vast range of correlated studies that go to make up the sum of

human knowledge and economics. In astronomy and astronomical engineering, in physics and chemistry, in civil and mining engineering, in meteorology and in metrology and in mechanics, to say nothing of many other branches of science, do we find progress as the watchword and the theme that excites and moves the human brain to grander and better achievements. It is my pleasure, and an enjoyable privilege, to call the attention of this Society, in my retiring address as your president, to some of these lines of progress in which I have for many years been interested, and which I trust will prove of interest to you. I shall therefore present some thoughts on the refinements of modern measurements.

When Dr. Alfred M. Mayer, of the Stevens Institute, published his splendid papers on the minute measurements of modern science in the *Scientific American* Supplement, some fifteen years ago, it opened the eyes of many of our American mechanics to the possibilities of a refinement in measurements they had never dreamed of, and I believe those papers, written in such clear and untechnical language, have done an incalculable amount of good to mechanics, who to-day show it by their accurate work, to some of which I shall refer later on.

The day has forever past when we are willing to say or believe that "three barley-corns make one inch," nor is the advanced mechanic of to-day satisfied with his boxwood rule, graduated to thirty-seconds of an inch, save for the coarsest approximate measurements; but he must have his Brown and Sharp standard graduated to one one-hundredth inches for his *coarse* measures, and his micrometer gauges reading to one one-thousandth for his ordinary work. Even in our iron and steel works, the old-time wire gauge, that for a long time held its own, has been displaced by the modern micrometer gauge of infinitely greater accuracy.

My esteemed friend, Mr. George M. Bond, has said very appropriately, that "the arm of King Henry the First, or the barley-corn, though possibly furnishing standards good enough for that time, would hardly satisfy the demands of our modern mechanics or tool-makers, who work very often within the limit of one-thousandth of an inch, and even one-tenth of this apparently mi-

nute quantity, with surprising unconcern and no less accuracy." Prof. Wm. A. Rogers has also shown that many of our modern mechanics can calliper to one thirty-thousandth of an inch. These however are coarse, rough measures when compared with others I shall mention in the course of this paper.

In the domain of astronomical measurements great progress has been made of late years by the use of refined instrumental means, as well as the many methods devised for the elimination of instrumental errors. The divisions of the meridian circle have been brought to astonishing accuracy. I may mention two of the best dividing engines in the world, which I have examined through the courtesy of the constructors. Perhaps the most celebrated is that of the Repsolds in Hamburg. This wonderful engine has come through three generations of celebrated mechanicians, each one adding to its accuracy until now it seems to have reached the limit of human capability; in other words, as perfect as the environments of temperature, and other factors over which human hands and brains have no control, will allow it to be brought. The maximum error of the best circles divided by this engine equals 1.17″. This engine is not automatic, but each line is set by from one to five microscopes, and the division traced by hand.

The other engine is that constructed by Messrs. Fauth & Co., of Washington, D.C., and is entirely automatic in its work. It is a fine piece of mechanical construction, and does honor to the constructors, and when compared with the original dividing engine of Ramsden, which I have examined, and which was a marvellous piece of work for its time, it tells unmistakably the advance of modern mechanical appliances in that direction. The mean error of a circle recently divided on this engine for the Cincinnati Observatory, as determined by Prof. Porter, is not greater than 1.″0. The Heliometer is now playing a most important part in accurate astronomical measurements, and the work of Dr. Elkin of the Yale University Observatory, and that of Dr. Gill at the Cape of Good Hope, with this instrument, will, in all probability, give us a nearer approach to the absolute solar parallax than has yet been obtained; and this may be appreciated when you remember that

the uncertainty lies in the 3d° decimal place of seconds of arc, a quantity altogether inappreciable to ordinary mortals.

This instrument has been largely used in a determination of the parallax of the "fixed" stars, and such measurements are perhaps the most refined in the whole realm of astronomical studies, as no star yet has been found with a parallax greater than 0.9 seconds of arc, and most of those nearest to us are not greater than half that quantity. When it is considered that personal and instrumental errors must be eliminated for a period extending over one-half the earth's annual revolution, it is not to be wondered that in many cases the measure came out sometimes a plus—sometimes a minus quantity, with instruments used for the purpose before the Heliometer was brought into requisition. I should like to describe this instrument, which indeed has been wrongly named, but time will not permit.

The astronomical camera is also adding largely to accurate astronomical measurements. It was thought at first that the shrinking of the film on the negatives would make stellar distances an uncertain factor, but no less an authority than Dr. Elkin asserts that the photographic charts of the pleiades are as accurate for refined measurements as the stars themselves by the use of the Heliometer, and whereas many of these stellar measurements have to be carried on for years under some of the most trying conditions, by the photographic method, a few hours will photograph all the stars of a group, or cluster, down to the sixteenth magnitude, and then the plate may be leisurely studied and measured in the laboratory without hindrance from cloud, bad definition, or the thousand and one difficulties the astronomer meets in endeavoring to reach his ideal. I could dwell here for all the time at my disposal, but I dare not.

The stellar charts given to us by those grand fellows, M.M. Paul and Prosper Henry, of Paris, by Prof. Pickering and his earnest corps of assistants in Southern California and Peru, as well as other members of the photographic congress; the beautiful photographs of nebula, by Dr. Janssen, of Meudon, Mr. Common and Mr. Roberts in England, and Dr. Von Gothard, in Hungary; the wonderful pictures of the solar surface made by Dr. Janssen, all

show us the triumph of modern photographic manipulations. But the end is not yet. Commencing with the work of our own Dr. Draper and that of Dr. Huggins, we have spread before us to-day charts of stellar spectra which tell us of the physical constitution of those suns whose parallax is unknown, and whose light period may date back to the dawn of life upon the earth. It may be of interest to state that in this research, which has added so much to our knowledge of stellar spectra, the wives of Dr. Huggins and Dr. Draper have both assisted in the charming work, and although Dr. Draper has passed away, Mrs. Draper still carries on the work through Prof. Pickering, and Mrs. Huggins is still at her post at "Upper Tulse Hill."

One of the most wonderful results lately obtained in stellar spectrum photography is the discovery by Prof. Pickering that, at certain regular intervals, the K line in the spectrum of Zeta Ursa Majoris is doubled. The interpretation of this phenomenon is that the brighter component of this star is a close double star beyond the power of the telescope to separate, and that while the companion is rapidly rotating around the primary star, it displaces the lines one side or the other of the normal line, according as it is approaching or receding from the earth.

Two other stars have been discovered with this doubling of certain lines, and it would be difficult to predict what will be the result of future researches in this new field. I could dwell here for all the time at my disposal, but I dare not.

Time measurements in astronomical observatories have reached wonderful accuracy. When our big bell tolls the quadrant hours of the dial, we pull out our watches and are satisfied if we are within quarter of a minute. Fortunately, our astronomer at the Allegheny Observatory is not so easily satisfied. If the stars will but shine, he is not content if the error be sixty times less, *i.e.*—a quarter of a second; and I recently saw the figures for several days' "time" work, where the errors were not greater than three one-hundredths of a second. We all know the great benefit of this time, transmitted to our railroad centres, and if human ingenuity could but have the trains keep time with the stars, we should

never have the paradoxical phenomenon of two trains endeavoring to occupy the same track at the same time.

A recent instrument for accurate astronomical measurement, invented by Prof. S. P. Langley, and constructed at our works, is named by the inventor an occulting eye piece. Experiments have shown that the time of the occultation of a star may be readily determined with this instrument within one-twentieth of a second, and with experience the time may possibly be determined within one-fiftieth of a second, and this perfectly free from the element of personal equation.

In the construction of astronomical instruments greater and greater perfection is being reached in every decade, and the time has passed when the astronomical engineer is satisfied with "cut and try" methods as of old. The mathematician stands by him ever ready with the magic plus and minus, to urge him on to higher attainments, to reach as near as possible to the demands of nature's unalterable laws.. The object-glass of the telescope, that marvellous eye that peers into the fathomless depths of stellar space, is now brought to most wonderful perfection, and has almost reached the limit of human possibilities. The refinement of the measurements of its curves may be slightly comprehended by the uninitiated, when I say from personal knowledge and experience that the rubbing of a surface for a few seconds of time with the tip of the finger and the finest of polishing material, may ruin the accurate performance of the glass. The measurements of the curves sometimes reach to the sixth decimal place, and the artist of to-day can determine so minute a quantity with great precision and certainty. In modern investigations of the object-glass of the telescope, no one has done so much to bring it up to the highest standard of perfection as Dr. Charles S. Hastings of Yale University. He has just completed some of the most refined studies in this line that have ever been made, and, perhaps, since the days of Gauss, no such advancement in mathematical dioptrics has been made, which, carried out experimentally, is now yielding most remarkable results.

The work of Alvan Clark & Sons in this line is known to all, their latest triumph being the great Lick telescope.

Paul and Prosper Henry and Secretan in France, Schroeder, Cooke, Hilger, Common and Calver in England, Sir Howard Grubb in Ireland, Merz and Mahler, Repsolds and others in Germany, and I might add other very honorable names to the list who have done a good part in this, one of the most charming fields of modern research, but I must not dwell here further than to mention that in our own country we are rapidly taking an important place in astronomical engineering.

The construction of the mounting of the great Lick equatorial was most successfully carried out by Messrs. Warner & Swasey, of Cleveland, while the great telescope of twenty inches aperture is now well under way at the works of Mr. G. W. Saegmuller, of Washington, D. C., and both these firms have built, and are now building, smaller but no less perfect mountings for other observatories. It is hoped that we shall soon have standard dimensions introduced into all astronomical and physical instruments, and a movement has already been made in the right direction. It cannot come too soon.

In the realms of physical investigation and apparatus, great accuracy has been reached in the past few years. Let me mention one branch in which I have taken an humble part, namely, the production of optical surfaces and the ruling thereon of those marvellous diffraction gratings which have so greatly advanced the study of spectrum analysis. I can well remember when Nobert, of Pomerania, produced his first test-bands for the microscope, and when he produced his first diffraction grating, which, in its entire ruled surface, was but two centimetres square. To-day we are producing surfaces fifteen centimetres square, in which the error of curvature or flatness, as the case may be, is less than one two-hundred-thousandths of an inch; and on which Prof. Rowland has ruled one hundred and ten thousand lines with such precision that the error between any two of the lines is probably less than one three-millionths of an inch. With this instrument of research physicists have boldly entered into new and untrodden regions of nature, and are from time to time uncovering her hidden wealth to enrich the storehouse of earthly knowledge. I present for your inspection the wonderful map of the spectrum of the sun,

which has been so recently placed in our possession by Prof. Rowland. Here, spread before you, is the result produced by the use of the concave diffraction grating, untouched by the hand of man. Here, in the red end of the spectrum, you see the marvellous B group, never before photographed as you see it now. Here you see the great C line and here the D lines, one of which is plainly double, while you see thirteen lines between the D lines. I can well remember when the instrument that would show the one nickel line between the D lines was considered a marvellous piece of work. Passing over the thousands upon thousands of lines between the D lines and the H line, we stop for a moment to examine between the H and K lines. Here is Angstrom's celebrated map of the solar spectrum. If you will examine it you will see he places three lines between H and K. In this photographic chart before you, I count one hundred and twenty-one lines between the H and K. But here Angstrom stops with his chart, because the human eye fails to see satisfactorily much further; but on this photographic chart we have, beyond the H K group, more lines than in the whole of Angstrom's map, as you see extending about thirteen feet on the photographic chart beyond that which is visible to the human eye, and containing thousands of lines. The value in wave lengths on these charts is given within one one-hundred-thousandth of its true position.

Probably one of the most refined studies in which the spectroscope is now being used, is the determination of the stellar motion in the line of sight. No other instrument is as yet able to cope with this difficult problem. When a self-luminous body like a star is moving rapidly toward the earth, it is evident that it is advancing upon its own "waves" of radiant energy, thus shortening them. When it is receding from the earth, it is as it were running away from the waves of radiant energy it is given out, thus in effect making all these waves of greater length. When its spectrum is examined in a powerful spectroscope, the absorption lines are seen to be shifted toward the violet, if the star is coming toward us; if the lines are displaced toward the red end of the spectrum, the star is receding from us, and by the amount of this displacement the velocity may be determined. This study, however, is a

most difficult one, as at best the displacement is very small indeed, and it is only by the most refined and patient work that Mr. Christie, Astronomer Royal of the Greenwich Observatory, has given us our present knowledge of the motion of stars in the line of sight. Much is, however, to be hoped from the method of double displacement which Mr. Keeler expects to use with the great spectroscope of the Lick observatory, as also the photographic method already mentioned in connection with Prof. Pickering's work.

All this has been brought about by work of the highest character requiring refined measurements and manipulation, of which our forefathers knew practically nothing. But the end is not yet. Refined as these measures may be, yet finer and more critical are being done, and we are now constructing a machine called by its inventor, Prof. Albert Michelson, an "Interferential Refractometre," in which this same phenomena of interference is made the basis of measurement which lies close to the border land of human possibilities.

You are all aware that the various enlightened and civilized nations have standards of weight and measure that have slowly been evolved from the cubit, the span, the finger-length and the barleycorn, if you please. Intimately associated with the evolution of standards of measurements are the names of Kater, Bailey, Bessel, Airy, Bird, Troughton, Babbage, Ramsden, Repsold and many others I could name; but in our modern work perhaps few men have done more than our own Prof. William A. Rogers, whom some of you know personally. I here submit to you one of his decimetre standards, in which we have included standards for the centimetre, millimetre and hundredths of millimetres.

But, as I said, nations have their standards. On what are they based? The French metre is presumed to be one ten-millionth of the earth's quadrant, the English yard evolved from the barleycorn, etc., but the measurements of precision in our day demand an indestructible, absolute and unalterable basis for our standards, so that if they all be destroyed the original is still available. Prof. Michelson has chosen a wave length of sodium light as the basis for a new standard, a something that will remain forever of the same absolute linear value, or at least so long as the solar

system floats in the luminiferous ether that, so far as we know, pervades the entire universe. A wave length of sodium light is, roughly speaking, about one forty-two-thousandths of an inch long; or better, five thousand eight hundred and ninety ten-millionths of a millimetre. Now, as this is an appreciable figure, it is evident that any method proposed to measure its *absolute* value must be of the highest accuracy. The method devised by Prof. Michelson in the refractometre has certainly brought the work to marvellous perfection; for in a paper read by him at the Cleveland meeting of the American Association, he showed that the error was not greater than one part in two millions, and possibly would be made not greater than one in ten millions. Gentlemen, can you appreciate such a quantity? Yet here is a physicist, with a high ideal of perfection, taking the pulsations that are sent earthward by the sun, and by methods within the reach of human skill, actually recording them upon a standard bar immersed in a freezing mixture, and giving us a universal standard based upon the absolute value of a wave length of light. You may appreciate some of the niceties in the construction of this interferential refractometre when I tell you that in making some of the optical surfaces for use with it, Prof. Michelson demands an accuracy closely bordering on one millionth of an inch.

With the new instrument Prof. Michelson proposes to carry out advanced experiments on studying the coefficients of expansion of standards, etc., the coefficients of elasticity, and critical measurements of the indices of refraction of various substances. But I must not dwell here, though the theme is as enchanting as Fairy Land. Nations have joined together for the production of standards of weights and measures, and but recently our government has received its new set, of which I hope we shall have a full description in the lecture we are to enjoy from Prof. Mendenhall on this very subject. It may be of interest to you, however, to mention the fact that Prof. Wm. A. Rogers, formerly of Harvard Observatory, has devoted the better part of his life to studying the errors of standards in use in this country and Europe, as well as producing some of the best work in this line that has ever yet been done. Perhaps no living man has worked so earnestly upon

his hobby. For years he got out of his bed at five o'clock every morning to compare his bars of bronze, steel, copper and glass, at an hour when they had swung through their oscillation or temperature changes, so as to be able to determine the absolute value of their coefficient of expansion, as well as to learn whether the material from which the standards were made passed through slow molecular changes or not. Among many important facts he has brought to light, is that of the equable expansion of metals, etc., *i.e.*, that the expansion is equal for each degree within a range from zero to the boiling point, so that it is now only necessary to know the coefficient for one degree, and add or subtract from the standard temperature at which the bar was normal. In the production and ruling of these standards there are so many factors that come in as hindrances to perfect work, that Prof. Rogers must have added to his virtues, that of patience to a very large degree. I have no doubt some of our members call to mind his paper, read in Pittsburg some four or five years ago, before the National Association of Mechanical Engineers, on "A Solution of the Perfect Screw Problem." The great Whitworth said, "a perfect screw was never made," and perhaps he was correct, but Prof. Rogers has brought its solution about as close as any living man, except, perhaps, Prof. Rowland, who indeed makes the best screw possible by mechanical means, and then by studying its errors, eliminates them by one of the most simple, yet beautiful devices, ever applied to the solution of so important a problem. Those of you who may be interested in this matter, will find a most excellent article on the subject by Prof. Rowland under the title, "Screw," in the ninth edition of the *Encyclopædia Britannica*. I here take the liberty to show you a screw made under the supervision of Prof. Rogers in some of his earlier work. Its linear error is not greater than 0.00005 of an inch, but it has unfortunately a periodic error of drunkenness, that makes it useless for the purpose for which it was designed, though for purposes where it can be used in whole revolutions, it is perhaps equal to any ever made. It cost the labor of two of the best workmen of the Waltham Watch Tool Co., for 425 hours, at $1 per hour, so that it cost almost half its weight in gold.

One of the most delicate methods of studying a so-called perfect screw is to rule a diffraction grating by the aid of a diamond moved by the screw. If there are errors of drunkenness as in this screw, the interference is so irregular that no lines can be seen in the spectrum from the grating so ruled. If it is more nearly perfect, the imperfection is made known by false lines or ghosts in the spectrum, and like Banquo's, they will not down until the errors of the screw are eliminated. There are many other methods of determining errors in the run of a screw, some of them of high value, and it is with considerable pride that I say our American machine shops are taking advantage of them to produce better and better work.

It needs no words from me to call to your mind the vast strides that are being made all around us in electrical science, nor is it my intention to elaborate upon the subject. But in connection with the theme of this paper, I may mention the great improvements being constantly made in the refined instruments for electrical measurements. When I call to mind the first induction coil made by Faraday, and which only a year ago I held in my own hands, I compare it with the beautiful and thoroughly practical instruments made within the sound of my voice. Is this not a marvellous age of improvement? Not only do we have our am-meters, our volt meters and our galvanometers measuring currents so minute as one hundred millionths of an ampere as well as the most enormous currents of electric energy, but made just across the way we have our electric metre, measuring out to you and I, the "subtle fluid" in quantities to suit our most fastidious tastes.

I may mention here that science is largely indebted to a little instrument called by its inventor the "Bolometer," for some of the most charming discoveries ever made in the realms of radiant energy. It is essentially an electrical instrument, as its action depends upon the resistance to a feeble current, by a most delicate strip of platinum, which when connected with a delicate galvanometer at once registers forms of energy coming to the earth from the sun, hitherto unknown, yet of so important a nature, that did it not exist, life would not be possible upon this planet. It has brought us news from the sun and moon that gives new life to the study

of what Prof. Langley has well named "The New Astronomy." The delicacy of the measurements made with the bolometer may be appreciated when you learn that under certain conditions a deflection of one millimetre on the galvanometer scale is registered by a current of 0.000.000.000.5 (five-billionths of an ampere) through the coils of twenty ohms resistance, and when the observing telescope is used on the divided scale, one-tenth of this deflection can be readily determined, and if we put this in temperature coefficients, one-billionth of a degree centigrade can be indicated, while 0.000.001 of a degree may be indicated and measured. It is with such an instrument that Prof. Langley has opened a new world to us, particularly in the infra red end of the spectrum, and has told us in the plainest terms that were it not for the invisible rays of radiant energy (invisible to the human eye) human life would be an unknown quantity upon the earth. But I must not dwell on these enchanted grounds, else I may be arrested by the fairies who have no love for long-winded people.

In the domain of civil and mining engineering most of you are far better posted than I, and I would waste time were I to take too much of it rehearsing the improvements due to accurate work and measurements. Constant improvements have been made in engineering and mining instruments within the past decade, and I have been much pleased in my work as an instrument maker to receive some of the very best suggestions from our thoroughly practical engineers. Improvement in micrometers in use in geodetic work have been suggested that are of great value, and constant efforts are being made by our instrument makers to bring them up to the highest accuracy for measurement. In the United States coast and geodetic work the constant aim is for work of precision. As an instance, I may note a recent triangulation in southern California eleven miles in extent, in which the mean error of three sets of observations was less than *one centimetre.* These observations were made by and under the direction of Prof. George Davidson, who was our representative at the late Paris Congress of Engineers. It is to be hoped that our esteemed head of the United States Coast Survey, Prof. Mendenhall, will use his best efforts to send such men to represent and carry out the work

for our government when the nations shall again measure the Peruvian arc as has already been proposed. We have advanced so far in our instrumental construction, in the character of our transits, theodolites, levels, heliographs, etc., that instruments of precision will not be lacking, if we can only furnish that important factor, the eye and brain at the small end of the instrument.

The accurate methods of alignments in the construction of long tunnels have been one of the wonders of the century. As I stood at the Swiss terminus of the great St. Gothard tunnel, my mind's eye carried me through its forty-nine thousand feet of solid rock excavation, executed by the hand of man, guided and directed by men of brains, alignment and levels measured and carried along from step to step until the diaphram became thinner and thinner, and at last Italy and Switzerland shook hands over this triumph of modern engineering skill. The alignment proved true to ten centimetres for level and twenty centimetres for the lateral line. But engineers are not yet satisfied with their achievements. Only a week since I learned of a proposed method of optical alignment that in my opinion will be of the utmost value in work of precision. I should prefer to mention the method, but as its inventor has not yet brought it to perfection, I could not do so without a breach of trust.

Chemistry is also adding to its laurels in the domain of accurate analysis and work, and indeed, while the spectroscope may detect the one three-millionth of a grain of sodium, we have yet to look to the chemist for those highly accurate determinations of quantitative analyses now so commonly characteristic of the modern chemical laboratory. The wonderful development of this beautiful science has perhaps contributed more than all others to supply the wants and necessities of the human race, and there is scarcely an industry to-day that is not in some way dependent upon the chemist for data upon which to carry on their work. So fully does this science enter into the industries of our own city, that every leading rolling-mill and steel works has a completely equipped laboratory and practical chemist, to supply from time to time accurate analyses of their products. Further than this, some of our own honored members are earnestly working toward that

which must come sooner or later, namely, standard chemical equivalents in the various grades of steel and iron. Let us give them our earnest support in this important work.

In mechanical appliances and in modern machine work great strides are being constantly made toward greater and greater perfection, and, as I said in the outset, the mechanic of to-day is not satisfied with the coarse measures and gauges of our early days; but he must have his steel graduated rules, his micrometre callipers, his standard end-gauges, his standard reamers, etc. What the English nation owes to their Whitworth, we, in turn, owe to such firms as Brown & Sharp, Pratt & Whitney, Sellers, Bement, Warner & Swasey, and others for their valuable contributions to metrology, and their standards of various kinds that have contributed so much to advanced mechanics in this country. The standard measuring devices made by Brown & Sharp, including their micrometre calliper, micrometre gauges, Vernier callipers, etc., their hardened steel squares and angles, etc., have become a power for accurate work. I notice it particularly in my own works, where my own excellent workmen have a most laudable ambition to read to the finest possible quantities in their mechanical manipulations, and, as a consequence, we are brought nearer and nearer to that devoutly to be wished for millennium, when interchangeable parts will be the *rule* and not the exception. The standard gauges, reamers, taps and dies of the Pratt and Whitney Company, now find an honored place in all high-class machine shops; and our American machinists are greatly indebted to the labors of Prof. W. A. Rogers and Mr. George M. Bond, who designed and carried into execution that wonderful instrument of precision called the Rogers-Bond comparator, from which has emanated so many standard tools, and which has assisted so largely in the introduction of interchangeable parts in American machinery. Every advanced machinist should read the admirable work published by this company, and edited by Mr. Bond, on standards of length. I am not saying this as an advertisement of any firm, but wish to give credit to our Yankee brethren who have done so much for work of precision in the machine shops of this great country.

But we have yet much to do to bring up mechanical work to the

standard it should be brought to. A few of our best shops have their tool room and a competent man in charge of it, but the day will come when the comparator will be in every tool room, when records in thousandths of an inch will be kept of the size of every important piece of machinery. The mechanic in charge will adjust every gauge and calliper by the comparator, and hold the workman responsible for his work. Watt thought he had attained remarkable accuracy when he bored one of his cylinders so that he could not get half a crown between the cylinder and piston-head. But we are not living in Watt's time, nor in the age of the old Cornish engine; and although we are not to despise the days of Watt and the Cornish engine, we have no excuse, in this advanced and enlightened age, to turn out indifferent work of any kind. Nor is it necessary to dwell on the importance of this accuracy of work in our machine manipulations, for while we have not yet reached an universal standard of interchangeable parts in our machines, every important firm in this country is doing a good share in advancing the grade of their output, and in good time we have reason to believe that precision will take the place of carelessness, and that excellent "rule of three" instead of that ancient and dishonorable "rule of thumb."

It is true that human hands and human brains must have a limit to their capabilities; but where shall we place that limit? Watt gave us the horse-power as a unit of measurement, Joule gave us the better one of the foot-pound unit, King Henry's arm may have served for the long measure, and the barleycorn for the short measure, but the metre and the micron are infinitely superior, yet we still hope for better standards, and are now reaching out for waves of radiant energy from which to make them, and which shall remain as constant as the universe, "whose builder and maker is God."

In the realms of the higher sciences the mind of man has reached, as it would seem, almost to the infinite. The mind may think and think, but human ingenuity is surrounded with so many hindering environments, that it cannot execute the commands of the brain; but we can approach to that boundary line where the

sign-board tells us, in unmistakable characters, "thus far shalt thou come, but no farther."

Sir Wm. Thompson has estimated the size of the molecule to be somewhere between one two hundred and fifty millionths of an inch and one five billionths of an inch, and in that beautiful illustration familiar to most of you, tells us "if a drop of water were magnified to the diameter of the earth and the molecules magnified in the same proportion, that the smallest as noted, would be coarser grained than a heap of small shot and the largest, less in diameter than a heap of cricket balls." Can we therefore ever hope to deal with such infinitesimal quantities? possibly, probably not and yet who can tell what a day may bring forth. The organs of sense in man have some marvellous capabilities. The human retinal nerves, for instance, have astonishing powers of discrimination. Prof. Rood has shown that a flash of light lasting but forty billionths of a second is capable of making an impression upon the human retina. Prof. Langley has shown in his charming monograph on "Energy and Vision," that the visual effect produced by any given constant amount of energy varies enormously with the color or wave length producing it, and that while we may perceive a white light in so short a time as Prof. Rood has shown, yet for the actual physiological processes required in seeing, we require from one quarter to one half a second. He then shows that the *vis viva* of the waves of light whose length is 0.75 microns long, when arrested by the human retina, *represents* work done in giving rise to the sensation of crimson light, of 0.000.000.000.0003, or three ten trillions of a horse power, or about 0.001 one thousandth of an erg, while the sensation of green can be produced by 0.00.000.001, or one hundred millionths of an erg. Moreover, he has shown that the human eye has a vast range in the intensities of lights it can perceive, represented by the ratio of 1 to 1.000.000.000.000.000, or one to one quadrillion. Prof. Nichol has also shown that some human eyes are capable of discriminating tints of color so rigorously as to detect one part of coloring matter in one hundred million parts of white. Here, then, I have given you a few instances of the remarkable powers of one organ of the human economy, an organ that we use

so constantly in all our refined measures and manipulations. Who then can tell the limits of human capabilities for grand achievments in the future? The world's great workshop is open for all of us. She needs master workmen. As the laws of mother nature are more unalterable than those of the Medes and Persians—and if we shall pursue our work in conformity to their demands, so shall we ever make progress toward perfection, and although the goal may never be reached, there is a happiness and triumph in knowing we have taken steps in advance of those before us, and have set the example of patience and progress to those who will follow after us.

> Let us then be up and doing
> With a heart for any fate.
> Still achieving, still pursuing,
> Learn to labor and to wait.

The Society adjourned at 10.15 P.M.

B. SPEAR,
Secretary, pro tem.

FEBRUARY 18TH, 1890.

THE Society met at their rooms at 8.10 P.M.

Thirty members present.

Director Wilkins presided.

On motion of Alexander Dempster, Thomas P. Roberts was elected Secretary *pro tempore*, Secretary Wickersham being detained at home on account of sickness.

The minutes of the last meeting were read and approved, with the exception of the annual reports, the reading of which, on motion, was dispensed with.

On the call of reports from committees, Mr. Dempster read the report of the proceedings of the convention in Harrisburg, January 23d, called by the State Board of Agriculture to discuss the subject of changes in the laws affecting the public roads throughout the commonwealth. Mr. Dempster had been appointed by the board of directors to attend that meeting as a delegate from the Engineers' Society.

Report of the Delegate to the Harrisburg Convention, January 23d, 1890.

About one year ago it was your pleasure to appoint a committee to consider the "Road Problem," and present such suggestions for its solution, in this commonwealth, as might appear practicable. The necessity for hasty action was so imperative (made such by the early adjournment of the legislature) that your committee did not have sufficient time in which to collate an exhaustive report, nor digest fully the provisions of a law that would embody the reforms necessary to transform our present code of road laws into a system that, in its practical operations, would give the greatest return of benefits for the amounts expended in the construction and maintenance of the highways of the commonwealth.

The members of your committee, impelled by the inclination to contribute their share in the accomplishment of the object desired, busied themselves in collating data, formulating a report and suggesting what seemed to them desirable provisions of a law relative thereto, which they presented to you at the meeting last March for your action, and which you were pleased to approve, order to be printed and sent to the legislature, in the hope that it might receive favorable consideration by the law-makers of the State. Before it reached the point of distribution amongst the legislators, it was decided (and I think very wisely, too) to postpone further consideration of the subject until the following term of the legislature.

As a result of such action, our proposed law was "shelved" "pigeon-holed" or sent to the "waste basket," and "thusly" our "labor was lost," so far as receiving any attention by the persons for whom it was intended. The recommendation of the Governor relative to the improvement of our roads had the effect of stimulating a number of persons, law-makers and others, to go into the business of offering something better than we had *on* our statute books. Many of the bills offered were specimens of crudity, and bore the unmistakable ear-marks of haste in preparation of "undigested ideas." Our own presentation might be classed in the same list. The apparent incompleteness of all the bills pro-

posed, and the lack of time in which to properly mature a satisfactory law, added to the importance of having the embodiment of the *best* judgment, the fullest information and enlightenment on the subject, induced the legislature to intrust the formulation of a law to a commission constituted of five members of the House of Representatives, three of the Senate, and five citizens appointed by the Governor. Thus the whole subject was left to be matured in the minds of said commission, and the provisions of a law to meet the requirements of the case to be formulated and moulded by them.

The appointment by the Governor of the citizen members of the commission was made about the close of the year, amongst whom is our "honored townsman and fellow-citizen," David McCargo, Superintendent of the A. V. R. R., as one of its members.

The various bills which had been presented in the legislature prior to adjournment (ours was not amongst them) were collected and bound into pamphlet form and placed at the disposal of the commission for their perusal if they so desire.

The members of said commission met and organized for the work assigned them, in the city of Harrisburg, on the 22d of January, which time and place were opportunely coincident with the annual meeting of the Pennsylvania State Board of Agriculture and General Farmers' Institute; who actuated, too, by the desire to contribute their quota of force to the already increasing current of public interest, had, through their executive and advisory committees, made the question of "road laws," "road construction," and "road repairs," the leading topics of their meeting, and which occupied their full attention. On Thursday, the 23d of January, in order that the consideration of the subject might be made the more general and profitable, and that all sections and all interests might be represented and heard, they had extended a general invitation to all agricultural and other organizations interested therein to send delegates to said meeting, empowered to express their views on the important points to be considered in connection with the general theme. Thus the members of the commission had the opportunity of hearing the subject discussed by the fully accredited representatives of the agricultural interests

of the State, and who are the embodiment of the wisdom, judgment and ability of the farmers of our State—and abundantly qualified to speak for, maintain and promote their interests. From the expressed opinions the commission no doubt quietly housed away in the granaries of their minds, gleanings of wisdom and thoughts expressed ably and well that may prove beneficial to them in their future deliberations, and of which we may realize some benefits when they are crystallized in the report of said commission. It seemed to be the earnest desire of the State Board of Agriculture to elicit as much information as possible on the subject, and of the commission to absorb as much thereof as they may deem essential in their work.

There were delegates from the States of New York and Massachusetts, who, with those from our own State, agreed without exception that the need of some change for the betterment of our roads was urgent and great; all can unite on this line.

It pleased your Board of Directors to send a delegate to that meeting for the purpose of showing the interest *you* feel in promoting the needed reform. He, in company with the delegate sent by the Chamber of Commerce (and who is a prominent member of our Society of our city) and another member of our Society who is enthusiastic in the promotion of every good work pertaining to public improvements, Arthur Kirk, Esq., attended the convention, arriving on the prompt time, in fact 24 hours sooner than was necessary, through the misinformation contained in a telegram to Mr. Kirk of the time that the subject would be taken up by the convention. According to the programme, the consideration thereof was assigned to Thursday morning, January 23d, at 9 o'clock. At the convening of the meeting, the Governor of the commonwealth took the chair, and proceeded in his usual able and eloquent manner to review the road laws of our State, and point out their defects, making suggestions relative thereto. His earnest and forcible treatment of the evils existing and the benefits to be attained by a sensible reform in the laws of the commonwealth, so as to bring their provisions within the operating lines of "common sense" was clear and convincing; but it would

occupy too much time to give even a synopsis of his speech, so I will not attempt it.

He was followed by N. T. Underwood from Wayne county, who read a carefully prepared paper on the "Public Road System," the whole tenor of which was, that there was a *want of system* in the great diversity of regulations prevailing in the different counties of the commonwealth produced and placed in the statute books of the State by the pernicious class legislation of the bygone years preceding 1874.

The next paper, entitled the "Road Laws of Pennsylvania," read by Mr. J. A. Gundy, of Union county, followed in the same general strain of adverse criticism on the present laws. These papers will be published, and no doubt copies thereof will be placed on the file of the Society. Thus the subject in all its different phases and principal features was brought clearly before the convention and discussion elicited. Wm. H. Rhawn, Esq., Chairman of the Board of Trustees of the University of Pennsylvania, opened the discussion by referring to the interest manifested by a number of gentlemen of that city, who had inaugurated a movement well calculated to call attention to this subject, by offering cash premiums for the three best papers on "Road Making and Maintenance." He showed that there was a general dissemination of interest in the matter. His speech was supplemented by Mr. Lewis M. Haupt, who in a very carefully prepared statement of facts, which might be termed a "scientific treatment" of the subject, illustrated the worse than extravagant waste of horse-power at present required to move the products of the farm from their initial point of production, to market, or to some of the great rail or water highways in the State. His comparisons were of different classes of roads and of the comparative cost of moving a ton on any of the roads, taking as the standard the cost of transportation of a ton of ocean commerce. The comparisons were interesting and fully convincing as to their correctness. The dissemination of "bright rays of wisdom" from those "wise men of the East" was well supplemented by the not less brilliant and perhaps more practical from the western metropolis of the Keystone State. I mean the delegate sent by the Chamber of Commerce of our city,

who, in his usual vigorous style, portrayed most lucidly the benefits that would accrue to the inhabitants of our commonwealth as the natural and legitimate results of good roads, and when he sat down I regretted that he had not been sent as the accredited delegate of the Society instead of that of the Chamber of Commerce. Your representative, fully impressed with the force of the facts that had been thus presented, deemed that the line of discussion which had been followed had fully and clearly expressed all that could profitably be said in that direction at that time, and believing that the "physical features" of good roads will be cleverly dealt with when the time arrives in which the engineer will be given opportunity to display his talent and ability in "road making" (for it is not because there are not engineers in the State of Pennsylvania that there are bad roads, and not because of any lack of ability possessed by the members of the profession that they are not properly maintained; for a thousand engineers could be found if their services were needed, who could and would construct good roads), endeavored to change the trend of the discussion into the channels of present requirements, and attempted to show that the urgency lay in providing *ways* and *means* which would enable the engineer to exhibit his ability in "road making," and to conclusively prove that such is not a "lost art," and, as speaking for the Society, he took the copy of the proposed law which you had approved last March and attempted to show that it was worthy the candid consideration of those entrusted with the revision of the present law, yea, that it was worthy of their support, approval and adoption in at least some of its provisions.

He does not flatter himself nor congratulate you that his attempt was satisfactory to those who heard, as it was not certainly satisfactory to himself; and the most he reports in the case is that the benefits that would accrue to the public by the enactment of the law approved by this Society would certainly prove greatly beneficial to the interests of the people, were tersely, though not eloquently presented; and as the authorized commissioners for the revision of the law were present, the benefit accruing from having their attention thus called to the recommendation of the Society and the results of its efforts in that direction were given a place

amongst the many suggestions in the form of legislative bills, that had been collected into pamphlet form as before stated; so that to that extent your delegate was successful and the object of your sending him to the convention at least partially attained and the Society placed in the foreground as an advocate for the necessary reform. Amongst the multitude of those who are laboring on the same side there are many who want to attempt too much and scatter their energies over the extended area of the whole field, but it seems to be the part of wise judgment to concentrate all our efforts on the requirements of the "legal stage" and after the best that can be procured in that direction has been obtained, then take up the next or "scientific stage," if you choose to call it so—treat it intelligently and well, and evolve the best that the professional ability of the State can produce. No fear need be entertained, no, not for a moment—that the profession will not be equal to the demand and the strictest exactions of an economic and practical application will be met to the full. I do not think it is yet the time to engage in the discussion of the "smoothest road" over which a team may haul the largest loads to town, or the greatest number of bushels of corn to the mill. That may come later and at a time that will be better than now. Many in following out their bent on that line would suggest expensive constructions which cannot be obtained as a rule, and have the effect of causing a feeling that they had better endure the evils of bad roads that they are thoroughly familiar with and have endured so long, than to fly to those of extravagance, the extent of which they do not know. Fearing the requisite increase of taxation, many will oppose any change, lest they should get too much change. I say, then, that the efforts should be limited to procuring the enactment of a judiciously-liberal law—the operations of the provisions of which would not be oppressive and still provide funds to enable the properly legalized authorities to construct roads by sections that would in a few years aggregate many miles of "good roads." The convention closed the discussion with the recommendation that the present law needs to be changed, that the custom of working out the road tax is altogether unworthy the support of an enlightened people, and that the construction of

roads should be placed under an intelligent head (they do not say an engineer, as that term seems to convey the idea of expense beyond their means). Beyond this I believe they did not go. Looking over the whole field, with the knowledge that the farmers are a power in politics although scattered throughout the State, whose influence is invested with potency in the framing of the laws by the operations of which they will be called on to pay money in the form of taxes, their opinions must be given consideration. The action that may seem to some enthusiasts too conservative, will more likely obtain desired results than any radical change by which the farmer would be unduly burdened, and in view of the present status of the case and the probability that there may be further opportunity tendered to express the views of the Society at some future time prior to the adoption, and may be prior to the offering of any proposed law, I would suggest the appointment of a committee on roads, to give the subject attention until such time as the Society is satisfied that it has accomplished its work along that line of utilitarian action. All of which is respectfully submitted by your delegate,

A. Dempster.

Upon the reading of the report, on motion of Mr. Davison the committee of last year, which had the subject of roads in charge, was authorized to continue its sessions, and report from time to time to the Society.

The members of this committee are: Thomas P. Roberts, Alexander Dempster, Thos. H. Johnson, Charles Davis, Arthur Kirk.

The Secretary *pro tempore*, by direction of the Society, cast a ballot in favor of the election of Simon H. Stupakoff to membership in the Society, Stupakoff having been recommended by John Naegeley and Charles F. Miller.

A. Dempster, then, as the regular order of business, read the following paper on the subject of

THE ROAD PROBLEM.

In following along the line of general ideas that have been advanced in promoting the movement for a revision of the "road

laws" of the State and the adoption of such amendments thereto as would make the operations of their provisions more effective in procuring a betterment in our road system, differences of opinion are expressed and divergent views entertained as to how such "betterment" can be best and most readily obtained. It is an old proverb "that in the multitude of counsel there is wisdom," and it may be truthfully said that the evolution of wisdom can be secured by a full and free interchange of opinions and untrammelled discussion of the subject submitted.

With this in view, it is my present province to present the "road problem" before you to-night, to educe from you the very "cream of your wisdom" and the best of your judgment; so that whatever action your committee (to whom you have entrusted the subject) may take in the future, its members may have the benefit of the very essence and concentration of your ideas thereon, hoping that the light thus turned on may reflect credit on our Society and make it a potent factor in the production of desirable results. My theme is not "road making," and my paper is not a treatise on the science and practice of "road construction and maintenance." Neither is it a compendium of the power and energy required to move a ton on the different classes of road from the properly maintained macadam road to the "mud roads" with which we are all now thoroughly familiar; nor a comparison of the good with the bad to convince you that "better roads" are a necessity. There is not a citizen within the confines of this broad commonwealth to dispute it, for every one (be he resident of the city or denizen of the country) agrees, that the evils and inconveniences to which we are subjected should be removed, and remedial measures inaugurated that would operate in the effectual transformation of the present system to a greater degree of efficiency, from which more beneficial results would flow. It is the unanimous opinion that some positive, earnest and energetic action should be taken without delay, towards procuring the desired end. Seldom, if ever, has there been such unanimity in the expression of public opinion as there is at the present time. The exceedingly wet weather of the past season has emphasized the great need there is for improvement in methods and scope of

our present road laws and their operations. The "country roads" have been almost impassable and the products of the farm have been kept in the "garner and barn" when they should have been taken to the markets of the cities and found their way into the channels of public consumption and been made contributory to the quota of nourishment that constitutes the bone and sinew of animal life. All are dependent on the offspring of the soil, as it is the basis of all material wealth; and the ways and means by which it can be most cheaply and readily transported from the initial point of production to the terminus of consumption enter largely into the economics of any country. Now, when the attention of the people of the State has been so prominently and generally directed to the subject, seems to be an opportune time to join in the movement, and by voice and action aid in directing public opinion in the proper channel and in giving point and purpose to the reforms that most clearly and explicitly lay claim to our approval, and endeavor to infuse into the movement such degrees of energy of action as its importance demands.

The transformation of the heterogeneous elements that constitute the practical operation of our road laws throughout the different counties of the State into such a condition of homogeneity, that they will be made responsive to the requirements of the times, and work without friction and loss of power in placing the necessary means at the disposal of the properly authorized officers of the State and locality, to enable them to carry into practice the theories and principles that intelligence and economy suggest in the practical construction and maintenance of our roads and highways.

It is a very easy matter to criticise existing evils, unerringly point out the radical defects of our present system, to unsparingly condemn the incongruities of the diversified provisions that mar our statute books relative to the repair of our roads, and to join in the general chorus for reform. But a practical solution of the problem—one that will meet all the conditions of the case—will be found difficult of attainment.

As balloons are not yet used as the vehicles for transportation of commerce, nor are the highways of commercial traffic, and the lines of social and domestic travel made of "wind," neither do finely

spun theories make a good basis for a solid road-bed; but as "money makes the mare go," so it is money that makes the roads on which the mare shall go to the best advantage, and the road problem of to-day is how shall we procure more money, and how shall it be more intelligently and economically applied?

I know and acknowledge that the money derived from the collection of the road taxes is not properly applied. The wheel of action has so long moved in the line of annual repetition, that it has worn a deep groove or rut of custom and habit in the popular mind, and it will be hard to remove it therefrom; but whenever the proposition is made to increase that tax, a pressure of resistance will be felt as a retarding resultant to such advance movement. If it can be shown that good roads can be procured without the increase of taxation, then there will be little or no difficulty experienced in effecting all the reforms that the most enthusiastic and sanguine promoter could desire. But the proposition or suggestion for improvement, however feasible and beneficial, if accompanied with the addendum that it requires more money and a larger tax duplicate, will not be found palatable to the popular taste.

When such a change is proposed as will require the farmer to mow, cure and put up a ton of hay, and take it ten or fifteen miles to market to provide ten or fifteen dollars to pay his road tax, instead of being permitted to engage in the "frolic" of working on the roads to that nominal extent, and thereby having the duplicate satisfied opposite his name, it will be considered of sufficient magnitude to make many think twice before they act; this, however, can be overcome, and the popular denunciation of the present evil has become so great that no opposition can stem the current.

If the surplus money needed for the improvements can be supplied without calling on the farmer for any extra amount to that which he has been accustomed to pay, then he will not likely demur; but any increase on him will be met with a frown. He earns his money, as a rule, by small aggregations; he labors early and late and all the year round, and counts by pennies the value of his toil. He feels that his farm is made the basis of the bulk of taxes; feels that he is contributing more than his share to the pub-

lic purse, and that he has been unjustly dealt with by the "powers that be;" and he is led to the conclusion, that whatever of increase there may be required, even for demanded and acknowledged improvements, should be derived from other sources than his well-tilled farm. This may be considered and termed narrow, prejudiced and selfish, unworthy the support of an intelligent and liberal people. But it exists, and must be taken into the account, in considering the opposition to be encountered and overcome in the allowances being made along the line of improvement.

The fact exists, and its influence must needs be dissipated by unanswerable argument in showing that the greater expense is the greater economy, and that the old methods have been conducted on the "penny-wise and pound-foolish" principle which operates to the injury of all concerned.

Let me, within parenthesis, remark, that the present system of working out the road tax is charged on the tax duplicate, and that the amount thereof is the price or measure of value of what has been paid for the actual results accomplished. The debit is not correct, for the amount actually expended in labor and skill could be procured in any market where labor is purchased at a fair price at often less than one-half what the books show as the supervisor's pay-roll; the other portion is dissipated beneath the tempting shade of some umbrageous tree by the wayside as the idle moments fly, when "country gossip" entertains the listening crowd. The receipts of the duplicate are more in name than in reality, and are absorbed without reflecting corresponding rays of benefit to the travelling community. The customs of the past that have crystallized almost into the formation of unwritten law require a refusion in the refining pot of common sense, and a recasting into the moulds of present requirement.

As it is the intention to so direct the present efforts that they shall evolve into a wise, intelligent and practical codification of statutory enactments that will best conserve the interests of the public, the public mind should be educated from the "old ruts" into the new and better methods adapted to the wants of the present time.

Arguments of the most convincing character must be adduced to

influence the taxpayer to unite and instruct the law-maker to alter and amend the fossilized statutes of the past that fail to meet the requirements of the day, and in the exercise of a liberal and wise discretion make provision for public necessities of the present régime. It should be clearly and logically shown that the farms strung along the lines of good roads will be greatly benefited; the day has been when the proximity of a farm to a turnpike was taken as an element of value, highly estimated by the owner, and fully discoursed upon when that owner endeavored to effect a sale. The same rule would operate now to the same extent as it did then, but, unfortunately for us now, and especially in this part of the State, we have not a "good road" with which to make comparison of the "bad." We do have a few fragmentary sections of the turnpikes of the past, but they are being worn down to the very "substratum of their constitution," and soon the last "coating" from the virgin clay will have disappeared, and unless the present movement will produce results to counteract the general decadence, all will be on the same level, and in seasons like this all will be "stuck in the mud."

In the urgent desire to get away from the present "environment of mud," and to attain to the highest plane on the line of improvement, there may be the inclination to go beyond the limit that public opinion will ratify and support. The danger of rebound from one extreme is to carry to the other extreme, as if the point which constitutes the centre of gravity, and the point at which it will eventually settle, was entirely unworthy of notice. That may have its illustration in the present movement in the attempt of some enthusiastic reformers to accomplish what is unobtainable at the present time. It is certainly not the part of practical wisdom to place our markers so far in advance of the lines of "public opinion," that there is no probability of ever bringing that "opinion" up to it in "action." Whilst it is "good generalship" to keep pressing forward and to place his banners on the very parapet of the enemy's entrenchments, yet it is neither prudent, wise or practicable to attempt it in face of the patent fact that his banner would be captured and nothing accomplished by the effort. His advancements should be made with the probable surety of success.

So let ours be *towards* securing the farthest point of advance in the line of reform.

Employ all the advantages which can be made available in the movement; concentrate and direct the current of popular enthusiasm to the scouring out the shoals that would impede its progress and let the "mercury" that measures the public pulse rise to the highest degree attainable by the "warm wave" of public discussion; able and eloquent, if you will—but fail not to perceive the advance limits of the indicators that show the full extent of assured improvement. Under the influence of this general rule let us review the provisions of the law proposed by our Society as a substitute for our present laws on the road question, in order to derive the benefits arising from a maturer consideration of the subject and see wherein it would fail to meet the demands and supply the wants of public requirement in the case; remedy its defects and prune its excrescences with skilful but unsparing hand; so that our Society may occupy the position of prominence that the interest and intelligence of its members fully entitle it in the movement, and to which the clear judgment reflected in the proposed law may commend it. Though all roads led to Rome, all were not of the same importance to the great current of travel flowing to and from the "Eternal City," and all roads have not the equal prominence as public thoroughfares of travel now; and it is a natural classification to divide them into general grades—those that are the leading and direct avenues of travel to and from great centres of population and to which others act as mere "feeders"—and those which are the "feeders." The former constitute the lines of travel, while the latter act as links connecting the former into a conglomerate network of accommodation for the wants of the people, and on this basis the classification has been made into two divisions, viz., "highways" and "roads," names short and suggestive of the class to which they belong; they are explained in the draft of the proposed law and need not be here repeated.

It is a matter of small moment who shall make the classification, but it seemed that a commission of four men from the different parts of the county, and thoroughly familiar with the facts in the

case, with the engineer, would do the work as intelligently and fairly as any others who could be entrusted with the work. It may be that the county commissioners would have time to do the work, but this I very much doubt, as that body has its own special work to do, and which will be largely increased in case the proposed law should be enacted and go into effect. In counties where they are not so burdened, it might be a small saving to assign that duty as part of their labor, as it should be the aim of any reform neither to increase officials nor add to the burdens of the taxpayers by promiscuous distribution of funds or extravagant liberality in their amount, without reference to the services performed. Assuming such classification to be made, a serious and important question presents itself for answer: Who shall have charge, supervision and control over them? The character and importance of these thoroughfares naturally suggested the classification into two grades, and it would seem that those denominated highways and which are practically county roads, should come under the control of county officers, and who so naturally should constitute a board of public works, or public improvements, or of bridges and highways, if you please? As the county commissioners in conjunction with the engineer to whom shall be entrusted the duty of determining the amount and character of the work to be done under the special and binding limitation that a certain portion of the funds are to be applied to permanent improvement and to mere repair, and to be governed by such regulations as will secure fully competitive freedom to all inclined to enter the lists as bidders for whatever work can be properly done by the contract system.

Then the question occurs, Who shall have the control of the maintenance of the "roads" which are embraced entirely within the township lines? The township may be termed the first or lowest political sub-division that has officers elected to manage its affairs. The people now elect their own supervisors and other officers, a right they certainly have and should be permitted to enjoy. The evil is that there is no qualification required of the persons they elect as supervisor and in very many cases, sufficient I may say to make it the rule, that men are elected without the

qualifications necessary to make an efficient officer. When the supervisor is elected he has full control and management of the roads, and has no authority or counsellor by which he may be restrained or advised. The "tax duplicate" is placed at his disposal for the disbursement of which he is chargeable, and as a rule the debits standing therein against the several taxpayers of the township is commuted into *labor*—which, as I have before stated, is not judiciously employed; and if it were and the amounts paid into the treasury in cash, they would not be sufficient to make any permanent improvement on the roads, and before such can be hoped for there must be an increase made in the amount of road tax as well as the employment of intelligence and economy in its application.

It is an American principle, and one from which we would not detract an iota of importance or force, that the taxpayer should have a voice and vote in the election of the men entrusted with the expenditure of the money they pay into the public treasury for local purposes, and it is perfectly natural that they should endeavor and insist upon the maintenance of that right. On a line with this general principle, the committee deemed it proper to recommend the election of three road directors, who should be entrusted with the power of taxing and disbursing the money needed in the township for road maintenance and repair. Associated with these, as a board, would be the engineer clothed with such authority as would enable him to employ efficient laborers and assistants in the doing of the same intelligently and economically.

It may be asserted that these road directors, handicapped by the custom of former years, would not assess any greater amount, or at least not a sufficient amount, to better the condition of the roads in the district. Assuming this as granted, the roads would not be any worse and the money as now received would be more effectually expended under the direction of the engineer, which would certainly be a benefit. The limitation of expenditure to the line of 70 per cent. for repairs and 30 per cent. towards permanent improvement would add to that benefit, and would in a few years result in having some fairly good roads. The taking

away of this right would be very unpalatable to American citizens, and I do not think it should be attempted; besides, if a few "fogies" of the "old régime" would persist in a township here and there to the old habits, they would be so comparatively few that they would be looked upon as specimens of antiquity, and be interesting as relics of a by-gone age, and serve as landmarks for comparing the new with the old.

Another provision proposed, and one which is of rather a radical nature, but based on the principles of the greatest good to the community and public, and one whose benefits would be liberally strung along the line of coming years for the enjoyment and comfort of all who ride or drive or draw a load to market. I mean the method suggested for the location and opening of new roads, and changing the location and vacation of old ones. The road system of our State and country has been an evolution from crude and unnatural causes.

The early pioneer, wending his way through the virgin forests of our land, left his mark upon the trees to show the direction of his travel and direct the pathway of his feet, and that became the line of travel. His eager desire to avoid the ambush of the valley taught him to provide a securer path over the hills, and thus the shortest way was sought out between the points to and from where he was going, and that afterward became the bridle-path then the wagon-way of the backwoodsman, and adopted even as the highways of internal commerce, and were used as such until the bands of iron and steel, on smoother gradients laid, became the great highways of trade and travel. It is incumbent upon the engineer and those in authority to change the location of many of the roads that are practically obstructed by steep gradients, and in order to insure the elimination of personal interest or prejudice in establishing for all coming time the routes of travel, it is proposed to submit the location of roads to the said road directors and the engineer, the latter being limited in his action to the procuring of the best gradient, the shortest line, and the least damage and expense in construction, if you will, consistent with public utility. Thus and thus only should roads be determined. For the steepest gradient on a road determines the

amount of the load that can be hauled over the same, and if a road, say 10 miles long, should be for 9 miles of such grade that a team could haul a load of one ton over the same, and that of the other mile should be such that the same team could not haul a load of more than half a ton up it, then the load over the whole 10 miles is limited to one-half a ton with all its consequent loss to the person so hauling, or he must have extra horse-power to haul the load up the excessive grade, and thus lose one-half of the power thus engaged. Either of which cases is a loss that should be entailed for all time, as an encumbrance on the future generations. There may be some prejudices hard to be overcome in the accomplishment of this, but less than this should not be accepted.

The matter, too, of opening up the roads, when located, is also removed to a plane above the control of petty prejudices and small selfishness.

The board and the engineer having once proceeded in the line of their duty as defined and passed upon the opening, it is a way opened to travel that no man can shut by outside pressure illegitimately applied.

Another question is propounded: How are the revenues to be raised and the road and highway funds to be constituted and maintained in order to provide for the annual expenditures that will flow as a stream, large or small, according to the determination of the powers that be? The answer to this seems naturally enough to come in response: Let the roads that are local in their character and importance be provided for by the local authorities, and the funds necessary for their maintenance and repair should be provided by the people who are locally benefited. Burdens to be borne in proportion to benefits received is a law so fair on its face that it needs no further recommendation to secure universal assent, and with the thread of its provisions running through the whole line of requirements, there need be little difficulty experienced in adjusting any differences into the cushioning cavities. All *benefits conferred, have their corresponding responsibilities to be admitted and given*, and thus the county and State would be called on to contribute, or rather supply their proportionate share of the funds

necessary for highways and bridges, by which benefits extended are general in their operations, and which the general public are at liberty to enjoy.

A very important feature of the whole subject, and one which interests us professionally, is the qualifications of the man who shall have general supervision over all the work in all the townships of the county, and have oversight over all the work of the county. The work to be done is of such a character, that a large discretion must inevitably be placed within his reach. He must not only be a man of good judgment but a man of extended practical experience with men; a civil engineer of undoubted ability. He should have the power of appointment of all his assistants, and be made responsible for their efficiency and good conduct.

All the requirements relative thereto should be strict and fair. No man of proper ability need to be afraid of requirements, however rigid, provided they are within the bounds of reason, and this, I think, has been kept in view by the law proposed. There is, in close connection with the duties of the engineer thus defined, a matter that has received little or no attention in this State; at least, I am not aware of any; that is the geography, or, I should say, the topography of it.

This should also receive attention. The States of New Jersey and Massachusetts have made topographical maps of their territory and published the same; that of Massachusetts is particularly well done, and presents at a glance the whole country to a practiced eye in its varied features of hill and dale, and valley and mountain, and river and lake.

There may be an objection that the work will not be worth the money expended, but that is too contracted a view to be entertained by an intelligent, progressive people. In order to secure uniformity of action and regulations amongst the several counties of the commonwealth, and combine the whole under one general head, a "State Engineer" should be created, who would infuse energy and effectiveness into the county engineers that would entail great and at present unimagined benefits. One week in the year, conventions for the promotion of the welfare of the department and conferring blessings on the community,

could be held profitably to all, and much good that is now unthought of would flow through that channel. This needs no elaboration and no discussion to command commendation.

Much remains to be said, but the limits of this paper have been reached, and I will not pursue the subject further at this time, but refer you to the law already proposed for fuller details. The continuance of the Road Committee will place the members in the position of continuous interest on the subject and no doubt they will be able to offer something further by way of improvement on said law, and they stand ready to hear, as they desire to elicit all suggestions bearing on the subject. So please consider that suggestions and discussion are cordially invited, and accept the invitation.

Discussion.

W. G. Wilkins: Of the township adjoining Philadelphia on the west, some years ago A. J. Cassatt, at that time Vice-President of the Pennsylvania railroad, was a resident, and I believe is yet. He was very much disgusted with the way the road tax was worked out and the condition of the roads. He determined that a change should be made, and so he announced himself a candidate for township supervisor. He was elected, and horrified the farmers very much by spending the entire amount of the tax on a very short piece of road which he macadamized. The farmers had not been used to that sort of thing. They had been used to having a few dollars spent here and a few there and let that go. Mr. Cassatt continued his method from year to year until to-day Merion township has the best roads in the State of Pennsylvania. I do not think there is a road in the township which is not macadamized. The farmers now speak in the highest terms of what Mr. Cassatt has done. The roads of Merion township are the favorite drives outside of Fairmount Park, and the favored part of the county for bicyclists. The only expense that the township is put to now is a very small one for repairs from year to year. The principal amount of the tax is expended in summer-time in sprinkling the roads. Mr. Cassatt had water tanks put up at different points throughout the township, and the roads are kept well sprinkled.

Taking everything into consideration, they have the best roads in the State. If that method was pursued in all the townships, it would not be long before the roads all over the State would be in the same condition.

A. Dempster: In the proposed law, which was favored by this Society, there might be some changes of advantage, and I think it would be very well to take that law and see if there can be any improvements in it. Then we shall present it in such a way that it will have some effect. It must be so matured that there can be no flaws found in it. We must try to occupy with it the position we now occupy. I think it is the best bill which has been presented so far as practical judgment and good common sense are concerned.

T. P. Roberts (on being asked what was the heated discussion which had occurred between himself and M. J. Becker before the meeting was called to order): It came up in this way. It is a matter of some interest just now, as it had reference to an article in the *Dispatch*. I had said that I had read an article in the Pittsburg *Dispatch* in which the author, who signs himself a "Mechanical Engineer" (he is a very good writer), says that the Society of Engineers, and the persons who have been in attendance at these conventions, and passing resolutions endorsing macadamized roads, do not understand that this is the age of iron. The day of stone roads is over. He says that the road he would advise would be very much cheaper than any macadamized road, and it would be simply a line of plank in the road, with a flat iron rail, about six or eight inches wide, on the plank, of course making proper connections at the joints; that that would always be passable, because the wheels would be on this iron rail, and so would not have the shearing force that would be exerted on the road proper. If it is possible that roads will never get muddy, that would certainly accomplish a great object. I said to Mr. Becker and Mr. Dempster that I had lived for several years in South America on the line of the road across the Mantiquera mountains, on which coffee is carried very rarely in wagons, usually on the backs of mules; and that it was the muddiest road I had ever seen in my life. In the rainy season there I have seen mules die right in that road. There

is where the battle opened. Mr. Becker said he believed the story until I got to that point about the mule dying, and I had to make a little correction in regard to that. I may as well state that, because Mr. Becker will say I did not tell the whole truth.

When a mule became exhausted they simply removed the packs from their backs, and left them lying in the road, and then the buzzards came down and finished them. They pick the mules' eyes right out. I have seen many mules die right in the roads there, with the aid of this process.

This subject of roads is one of very great importance in my estimation. It is one that seems to engage the serious attention of engineers. The problems are very simple so far as the construction of the roads is concerned. What we want is the means to build the roads. I have been very much entertained by what Mr. Dempster has said to-night, but there is one point I do not think he has dwelt sufficiently upon. That is universal taxation provided for all over the State by the counties, so that all people should be taxed, particularly the railroad corporations, which are now exempt. It was brought out at the Harrisburg convention that the people of great wealth had gravitated to the cities, and the farmers are paying all the expenses; still, the farmers are entirely too poor to build roads, and so comes in very well this classification of roads. The county roads would be built by the general tax from the county. A very interesting point comes up in that connection that I have not seen any notice of. In the city of Philadelphia the people are very anxious to do something for the benefit of the roads all over the State. They had a very good delegation at Harrisburg; very intelligent gentlemen from the University of Pennsylvania, and others representing a large public meeting which had been held there, and at which George B. Roberts and a great many prominent business men of Philadelphia, wholesale merchants and others, were present. Now, under present city laws, they have the right to lay out the streets, and they can expend the money there, but they want the right to spend money also outside of the limits of their county. That is probably the only county which comprises simply the city itself. But the money cannot be expended out of the county without special legislation. Now the

question comes up, how can they make a law by which the wealth of Philadelphia can be utilized to assist in the construction of roads throughout the State? In addition to the general county tax, there may be some contribution from the State. In that way only can I see that Philadelphia can be brought in to help build the roads in the adjoining counties or throughout the State.

W. G. WILKINS: The remark Mr. Roberts has made regarding the State assisting in the improvement of the roads reminds me that the other day I was in conversation with a gentleman from New Jersey, and this subject was brought up. At that time I did not know that the subject would be brought up here or I would have obtained more information from him. For ten years he said they had been trying to get a State law passed which would allow them to improve the roads. They finally got one passed at the last session of the New Jersey Legislature. One of the points of the law was that there should be main roads selected from county seat to county seat, to be improved, and the State would pay for one-third of the cost and the counties through which this road passed the remaining two-thirds. It seems to me that the proposed law of Pennsylvania might include some provision of that kind.

A. DEMPSTER here read the provision in the proposed law covering this point.

T. P. ROBERTS: I had the impression that was to go to the general fund of the State; that it did not specify to be employed on roads.

A. DEMPSTER: Yes, it goes into the highway fund.

A. KIRK: I would take issue with the writer of the paper on one point, and that is that the township officers should have anything to say about the management of the roads. I was in favor of that at first until we further discussed it. When you put up any men of the township to decide about the road here you come into the local entanglements of relationship. They will say: "You shall not run it so as to cut my father's farm or my brother's farm, and all this and that," but if you make the location and management of the roads entirely independent of any local influence, then you will not only make good roads for the neighbor-

hood, but will make good roads for the State. A road is not the private property of the township. It is made for the State, and the State should have the control of where that road should be located, independent of any local influence whatever.

I have known cases where you have climbed one side of a hill, got up to the summit of it, turned at an angle of 45°, and described a mile and a half where half the distance would have done and the shorter line would have been almost on a level, but it would have cut my father's farm. All such nonsense as that would be avoided by having the same system applied to the roads that any intelligent railroad company does to the location and maintenance of their line, where you have a chief engineer; then you have assistants for this division and that division, and each has his assistants and so on down, and every man responsible for his part. If you have township officers to come in and interfere with this chain of responsibility, why it would be something the same as if the stockholders in the neighborhood had the right to appoint the track-layers on the road of the main line. It would just produce division and break down responsibility.

I admit there will be difficulty to have such a law passed. There will be difficulty to get any road bill passed, and we must see to it that whatever bill is presented shall be as perfect as we know how to make it; let us have an engineer to do the work or let them stick in the mud. There is no use in half doing the thing. It is just as easy to remedy the evils of it now, and it seems as if Providence had sent us a season to show all the evils of bad roads. There is mud all over the State, and we will never get the public mind in a better condition to call for public improvements.

One of the great objections is the increase of taxation. I think that we ought to start out with the idea, as a matter of fact, as a matter of policy, that there shall be no increase of taxation on farms. It is estimated now that we spend four millions of dollars annually in the shape of making roads. You give any intelligent engineer four millions of dollars to spend judiciously in making roads, and in a few years you will think you are in

another country. I do not think there is any necessity for increasing taxation one dollar.

It is just as much of a benefit to the cities to have first-class roads as it is for the farmers. It is as important to the Pennsylvania Railroad, as they find now by the limited amount of travel and business that they get at the way stations. They will find it would be to their interest, and I understand they are willing and ready to submit to taxation if necessary to procure good roads. I think if we start out to make a law it will be a law that shall be a perfect chain; no submission to any local dictation whatever.

A Member: I have heard no reference to the old classification of roads. There is a difference in the old classification. There are State roads in Pennsylvania laid out as such.

T. P. Roberts: Not now. There were State roads.

A Member: I suppose not since the change in the Constitution of 1874. I have not examined the subject, but we have turnpikes that were national roads, and we have State roads and we have township roads.

A. Dempster: I never heard of such a classification. Now, as to the comparing of roads with railroads. There is no comparison between the running of a railroad and the making of a township road. If you were to take a turnpike and say how the officers of that company should be organized, as compared with a railroad company, there would be some comparison, but there is none in this thing. Mr. Kirk is entirely at fault, so far as our present proposed law is concerned, in saying the road is left to these three road directors, because it is not. It is left to them with the engineer, and the engineer is limited to getting the best gradient. He cannot do anything else. Then he must take the shortest line, and that with the least damage. How better can you put it than that; the best gradient, the shortest line and the least damage. After the location has been defined and they have passed to the opening of that road, it is put in such a way nobody can close it. If the people are not satisfied the matter of damages comes into court but the road goes on. You may just as well accept a state of facts. If you take away from the people who pay the taxes the say-so in the management of

their local affairs, you may just as well attempt to turn the American Government upside down, because you can't do it. There are no people, not even Mr. Kirk, who would submit to anything of that kind. And now, having accepted as a fact, this principle that is engrafted in every American heart, that he must have representation where there is taxation, we must elect good men as a safeguard. Good men should be elected. They must be freeholders, and must have been freeholders in the district for three years preceding. These men, with the engineer, have control of the purely township road, but when it comes to the main roads, the State roads, from one county to another, they are classified in our law as highways. They are under the control of the county engineer. He is made responsible for good work that shall be carried on, and all his assistants are responsible to him and dependent upon him. This makes him a head and responsible for all the actions of his assistants, and he makes them responsible for their portion of the work. They, the road directors, are elected independent of him, but the law gives him full control, absolute power, you may say, in the expenditure of money. You do not take away from them the semblance of authority in the matter in this way.

A. Kirk: If that is the case, where does his colleagues come in?

A. Dempster: Now, Mr. Kirk, I put it to you fairly. If we were to pass such a law as you indicate, you would be about the first man to kick. There are no men who can go all over the State. You must concentrate and have local government. That was brought out at Harrisburg. It would never do to have the State take charge of the roads. You must localize them. If there was a State Superintendent or a State Engineer to take charge of the roads, what would it be? It would be worse than now, in a short time. There would be the cry of corruption, and probably, cause for it. We would not be able to stand it. That cannot be done. The best thing, in my opinion, is to get what can be gotten, as good, practical a law as we can; but so far as I know, and from the discussion I have heard on it, I do not see there is much improvement can be made in the law that was approved by you last March. There may be some little points that

would bear revision, but as a general line I do not think there can be much improvement on it.

J. H. Harlow: Suppose that board and the engineer would be at loggerheads?

A. Dempster: That might tie up the road, but the general thoroughfares are under the control of the county engineer, and they would not be affected.

A Member: What provision is made for the division of funds between the county and the township roads? What portion of the funds, of the general funds, is to be applied to the township; what portion to the county roads?

A. Dempster: This local board has power to assess what they want to spend on the local roads, and the county commissioners have power to assess for the highways. Then the treasurer is authorized to collect a certain amount of State tax to go into that highway fund, not into the road fund.

A Member: Does that special tax go into the general county tax?

A. Dempster: It goes into the road fund; the local road fund and the general road fund, and the State and county taxes go into the highway fund.

A Member: When the farmer pays his taxes, does he know how much his road tax is?

A. Dempster: Yes, sir; that is printed on the list.

A Member: What provision is made for the taxes, the general county taxes?

A. Dempster: Assessed as now. There will be no change in that respect.

T. H. Johnson: It seems to me that the vital points in this law rest simply upon these two features: First, in doing away with the labor tax and substituting a money tax for it, and then the other provision, which requires that a certain amount of that tax shall be expended in permanent improvements every year, and under the direction of an engineer. These two points must lead to good results. The other points are mere details.

A. Kirk: I rather think it will be necessary to have a road engineer, or whatever you may call him—a State engineer. If

every county is made independent of its neighbor, and has its own engineer—here is a road to be built from here to Butler—we will use that as an illustration. While that road is in Allegheny county, we will suppose it is in a tolerably fair location, but when it comes into Butler county, it runs through a district that they want changed for some cause or other, and they want to strike Allegheny county different from Allegheny county's engineer, who is to settle that point? It is not impossible to expect things of that kind. If we have a State engineer, he settles such matters.

A. DEMPSTER: Would you have a State engineer travelling all over the State locating roads?

A. KIRK: I would have more especially a State engineer to collect accounts and statistics of roads; to be a centre of information for every county engineer that wants it.

A. DEMPSTER: That is contemplated in the law.

T. P. ROBERTS: How is that 7 per cent. mentioned in the law expended?

A. DEMPSTER: It is put into the highway fund and expended by the county. Everything is done by the county and if there is a State officer he would be a head. The State Superintendent of Schools is something similar, and all the county engineers would report to the State Engineer, receiving general instructions from him so as to insure uniformity of action throughout the State.

A. WILKINS: If a dispute such as mentioned should occur, is there any settlement for it?

A. DEMPSTER: No, sir. There is no such provision. Such a case I think is purely hypothetical and imaginary.

M. J. BECKER: Among the fundamental principles of this government there is this general one which has been underlying all our institutions; namely, that the principle of self-government should be carried down to the minutest detail, and the pride of our institutions has been resting on that principle largely. And it would be somewhat difficult, as I can readily see, particularly among the rural population, to institute a measure which would deprive them of the exercise of that long cherished principle. At the same time it cannot be denied that with the changing circumstances and the rapid advancement of general civilization

throughout the world there is a tendency towards centralization in all governments.

The point that Mr. Dempster mentioned in his paper regarding the administration of affairs within the limits of the township and which was taken up by Mr. Kirk, strikes me as one that is entitled to some consideration. I can readily see that if we carry the administration into such close quarters and small subdivisions as townships that there would be a great source of trouble growing out of it, not only on account of the neighborhood considerations which Mr. Kirk mentioned, but the individual contests between two men occupying similar positions or the same positions in two adjoining townships. They might be perfectly honest and yet differ materially in their views as to how certain matters should be carried out. If there were a stubborn man in charge in one township, or one disposed to be ugly he might step you right in a mudhole while you might have good roads on either side for miles. Still these things are not much to be feared. It seems to me that the good common sense of the people will come to the rescue. I have seen that in my own experience, in cases that came under my personal observation, where streams forming the boundary lines between counties and States had to be bridged, and where conflicting views and varying interests were always adjusted satisfactorily to all concerned. I do not apprehend any serious trouble about that. The time for building what you might call trunk highways, running through the country for long distances, such as national roads, is past. Other means of communication have taken their places, and what is needed now is to establish short lines of communication between interior towns, roads leading to the depots of railways, harbors and steamboat landings. Things of that sort; that is all that is wanted, but they must be such as you can use. We would bring the control down practically to counties and townships and with the provisions of the law as I understand it there can be no very serious obstacle in the way of carrying out a series of improvements, progressive, as well as for the purpose of repairing and maintaining. Nevertheless I can see that some court of last resort, some place of appeal at the seat of the State government will be necessary to supervise the whole and

keep a fatherly eye over the administration of the local authorities. There might be cases where some appeal would have to be taken, just as in the case of the schools. It could be connected with some other office perhaps, but some place of last resort should be established.

Among the arguments that were heard in Harrisburg I have noticed several, and I was particularly struck with the remark made by some one, I do not now remember his name. After delivering a very fair argument in support of the subject, he wound up by saying, "Of course the railroads will oppose this thing."

Where the "of course" came in I cannot say, but it is illustrative of the generally prevailing superstition that a railroad opposes everything on general principles.

The remark which the chairman made regarding the improvement of roads near Philadelphia indicates that is not true. It would be absurd for railroads to oppose the building of good roads because it would actually be detrimental to their interests. If they are selfish they know what is best for them. They know a good thing when they see it. What is the use of having a railroad station if you cannot get to it. This statement is too absurd to require any controversy on my part. But while it is safe to say that railroad companies are in favor of good country roads, there are cases when they get more of this commodity than their proper share.

In Ohio, where they duly appreciate the necessity for good roads, they have adopted a somewhat different way for their introduction. They passed a bill called the free turnpike law, under which macadamized roads are built by a system of taxation on the surrounding and adjacent property. They take a map, and levy a tax on all property, say within a mile or a mile and a half of that proposed free turnpike, and the first thing the commissioners would do when they were appointed to locate a free turnpike was to look over the map and find where there was a railroad, and they would invariably locate that turnpike within the limits of that railroad's mile distance. Then they would tax that road for all there was in it. A railroad in Ohio, such a line as the Pan Handle for instance, is valued at $15,000 to $25,000

per mile. You take a rate of three cents per hundred and you see the railroads have built about all the roads in the State. That is an illustration somewhat the opposite of the argument of our friend at Harrisburg. They have done more in Ohio for roads than I hope they will ever be called upon to do in Pennsylvania.

The tendency that I mentioned towards centralization occurred to me just now as pretty clearly illustrated so far as railroads are concerned. Originally when they were built they were little neighborhood concerns built by the subscriptions of a few people. Their extent was limited. They have grown by aggregation, one line swallowing up another, until they have finally developed into large trunk lines, although they were not generally built for that purpose. This change in the direction of centralization is one of the causes which has made it necessary to establish an inter-state commerce commission.

If there is any provision in the law to establish in connection with it some supreme court at the seat of State government it will be a good thing. It ought to be provided for. I do not think the bill would be a good bill without it.

On motion, the Society adjourned about 10 P.M.

THOMAS P. ROBERTS,
Secretary pro tem.

MARCH 18TH, 1890.

Society met at 8 o'clock, P.M.

President Scaife in the chair.

Vice-President A. E. Hunt, Director M. J. Becker, and fifty members and visitors present.

The following applicants for membership were balloted for and elected: C. V. Kerr, S. L. Tone, J. A. Thorsell, Gustave Mueller, J. P. Edwards, E. G. Caughey and S. W. Black.

A. E. Hunt announced that the Iron and Steel Institute of Great Britain would sail from London about September 20th, the Institute of Mining Engineers meeting first week in October;

they will then start for Pittsburg to the International Meeting in this city.

Motion by A. E. Hunt that a committee of five be appointed by the president to co-operate with the American Institute of Mining Engineers in entertaining the visitors.

The following paper was then read by L. B. Stillwell :

PUBLIC SAFETY AND THE DISTRIBUTION OF LIGHT AND POWER BY ELECTRICITY.

To those interested in the problem of the economic utilization of electricity in America, the question of danger is the question of the hour. Not the only question, of course, nor even, perhaps, the greatest question; but, nevertheless, that question which stands out with special prominence and demands immediate solution. The perfecting of the almost innumerable details of dynamo construction, the designing of new and improved forms of indicating and measuring instruments, the improvement of the storage battery, the increase in the efficiency of incandescent lamps, the development of underground systems of conductors, the great possibility of transforming energy in the form of heat directly into energy in the form of electrification, without the intervention of the steam-engine and the dynamo; all these and others are, perhaps, problems of greater scientific interest, but the one practical question which everybody is just now asking, and which electricians must answer fully and satisfactorily is, can electricity be utilized without serious danger to life and property?

The causes which have contributed to bring this subject into special prominence are not difficult to analyze. The general facts at least are familiar to all. Within the last decade the electrical industries have taken their place among the great industries of the country. The telegraph and telephone are followed by the motor and the electric light. In the telegraph and telephone that property of electricity which especially appeals to the imagination is speed; in the light, and still more in the motor, we are impressed with the manifestation of power. In the telegraph circuit the energy is not great, in the telephone it is exceedingly little,

but in light and power circuits, hundreds and even thousands of horse-power are already employed, and it is but a question of time when even these figures shall be far exceeded.

The most recent statistics in my possession showing the extent of the use of this agent are those collected by the secretary of the National Electric Light Association, prior to the meeting of that organization in August, 1889. These statistics show, that at the time this convention was held, the number of arc lights in use in the United States was 237,017. The number of incandescent lamps was 2,704,768 (I presume this means 10 c. p. lamps). The number of street railroads operated by electricity was 109, comprising 575 miles of track and 936 motor cars. It was estimated that the capital invested in these industries amounted to $275,-000,000.

From these figures it may be roughly calculated, that in supplying these lights with current, and in operating these electric roads, a boiler and engine and dynamo capacity of 500,000 horse-power is required. We may not expect to employ such power as this without a certain amount of attendant risk. Man has never harnessed the great forces of nature without more or less difficulty and danger. The chances of accident are increased by the fact that the practical development of the science is so very recent. A large proportion of the men engaged in installing and operating apparatus are not thoroughly prepared for their work; many practical problems remain unsolved, and as to the theoretical analysis of the subject, the greatest of our electricians confess that they do not know accurately what electricity is. A series of shocking accidents has startled the public, and has called attention to the possible dangers of this unseen and in some ways mysterious energy.

In this country where everybody reads the newspapers and keeps fairly well posted as to progress, and where especial interest always attaches to the newest thing, a certain amount of information concerning the subject, for the most part of a vague and uncertain, and consequently credulous character exists. Anything electrical is of interest. Electricity in the eyes of the public is the symbol of the marvellous. Moreover, its laws are more or less mysterious, and nobody is able to say just what it may or may not accom-

plish; consequently, since we are fond of predicting great things, everybody has been telling his neighbor what he believes this new thing is going to do, and in general, the less a man knows of the subject the more marvellous are his predictions. The development of the science has been so wonderfully rapid, that even those actually engaged in the business are unable to keep themselves well-informed concerning all of its already numerous branches. Electricians themselves have been compelled to specialize, and in view of this fact, it is not strange that the interest of the public is as yet largely qualified by ignorance. In no other branch of science is this interest so general. It is therefore not surprising that the occurrence in rapid succession of some half dozen fatal accidents in one of our largest cities, has attracted universal attention, and has created in the public mind a distrust closely akin to panic.

Newspapers, ever ready for sensation, have seized upon the opportunity and have published harrowing accounts of the fatalities, having sometimes a foundation of fact, and in many cases, a considerable superstructure of fancy. Ridiculous as are many of these newspaper accounts, and unfounded as is the alarm of the public, the agitation of this subject is nevertheless timely, and the effect will undoubtedly be beneficial to the public in general, and to those directly interested in electrical work in particular. Fierce competition between electric lighting corporations, existing while this rapid development of the business during the past ten years has been going on, has resulted too often in careless and inefficient work. The great desire on the part of local companies investing in apparatus to realize the largest possible profit upon their investment, has, in many cases, prevented proper installation. The manufacturing companies have not always insisted upon careful running of circuits and use of safety devices. In their eagerness to close contracts those installing plants have often reduced their estimates at the price of reducing their factor of safety in operation. It is therefore, fortunate for the general interests of the business that a halt has been called.

In this paper I shall attempt a brief description of each of the methods of distribution commonly used, dealing only with the

more important features of each and omitting so far as possible minor details of construction and operation not essential to a general understanding of the subject. I shall endeavor to treat the subject from a popular rather than a technical standpoint. I shall point out some of the risks peculiar to each system and indicate some of those precautions by the observance of which these risks may be in greater or less degree obviated. For convenience and clearness I shall make the following classification :

First. Methods of supply in which there is direct electrical connection between the generator and the lamp, motor or other translating device.

Second. Methods of supply in which the energy from the dynamo is not delivered directly to the translating device, being modified in its characteristics of potential and quantity by the interposition of the transformer or converter.

In each of these classes we have three sub-classes, namely :

First, series ; second, parallel or multiple arc ; third, multiple series.

This classification in sub-classes depends upon the methods of running the circuits.

It will be most convenient to refer first to certain elementary definitions and laws, then to consider each of the sub-classes named, and finally to point out what modifications result in each of these sub-classes when the transformer is used.

An electrical circuit may be said to consist of a generator of electromotive force and one or more paths or circuits connecting the terminals of the generator. A dynamo without any paths or circuits connecting the terminals is simply a generator of electromotive force. When we provide circuits leading from one terminal to the other, current begins to flow, as we commonly say. This idea of the flowing of current is of course simply a fiction used for the purpose of lending definiteness to our conception and enabling us to speak intelligibly without going back to first principles. It is certain, of course, that nothing material does flow, nevertheless, the phenomena actually occurring have a general resemblance to the flowing of water, and the analogy is extremely useful. It is, therefore, common to speak of the current in an electric circuit as

flowing, and it is generally assumed to flow from the positive to the negative terminal of the generator.

As above stated a dynamo having no path or circuit connecting its terminals generates simply electromotive force. No current flows and the energy in the circuit is zero. The instant a path is provided between the positive and negative terminals of the machine, however, current begins to flow, and at that instant energy appears in the circuit.

Energy, then, is not represented by electromotive force, alone, nor is it represented by current alone, but it is represented by the product of these two factors. This is a fundamental statement and one that becomes of great importance as we proceed to consider the problem of the distribution of electrical energy.

To make this clear it is sufficient to suggest the common illustration of the analogy of a circuit carrying current and a pipe conveying water. Electromotive force in the former finds its analogue in the pressure or head of the latter. The current in the electrical circuit is not accurately represented by the quantity of water flowing through the pipe, since our definition of a quantity of water flowing, as so many gallons per minute, or per second, combines the idea of rate of flow with the idea of time. If, however, in the case of the electrical circuit we substitute for current quantity, by multiplying current by time we have a strict analogy between quantity of electricity and quantity of water.

The energy represented by water flowing from a pipe in a second is proportional to the product of the head or pressure and the quantity of water which flows in that second. In like manner the energy in the electric circuit in a second is equal to the product of the electromotive force and the quantity of current. It is evident that since in each of these cases the energy is represented by the product of two factors, its amount may be varied by varying either of the factors. In hydraulics a certain definite amount of energy may be represented by a head of 746 feet and a flow of one gallon per second, or it may be represented by a head of one foot and a flow of 746 gallons per second. In electricity, similarly, a horse power may be represented by an electromotive force of 746 volts and a current of one ampere, or it may be represented

by an electromotive force of one volt and a current of 746 amperes. That we may understand the bearing of this fact upon the problem of electrical distribution it is necessary to refer to another fundamental law, namely, that which expresses the loss of energy in a circuit. The law is, that the loss of energy in any circuit conveying electricity is proportional to the square of the current multiplied by the resistance of the circuit.

For a circuit having a certain resistance, then, we quadruple the loss every time we double the current. That loss does not depend upon the electromotive force employed. It varies only with the current.

Now suppose that it is necessary to supply energy to two motors placed in independent circuits, and suppose that the resistance of each circuit outside the motor is equal to 1 ohm. Assume that the energy to be delivered to each is equivalent to 1 horse-power, that is, to 746 watts. To the first motor, let this amount of energy be supplied by delivering 10 amperes at a pressure of 74.6 volts. To the second, let 1 ampere be supplied at a pressure of 746 volts. Precisely the same amount of energy is delivered in the two cases, and if the motors used be properly constructed the results, as far as the motors are concerned, should be equally satisfactory. Now, consider the loss in the circuits outside the motors. In the first case, 10 amperes were forced through a resistance of 1 ohm. The loss in energy is found by multiplying the square of the current by the resistance, and is equal to 100 watts. In the second case, the loss estimated by similar calculation is 1 watt. Comparison of these two cases shows that by increasing the electromotive force ten-fold, the loss in the conducting circuits, which is, of course, simply waste of energy, is in the second case reduced to 1 per cent. of its value in the first case. It appears from this, that as far as loss of energy due to the resistance of conductors between the generator and the motor or other translating device is concerned, it is very expensive to carry current, but costs nothing to convey pressure or potential.

The law may be stated as follows:

To convey a given amount of energy, a given distance with a given percentage of loss in the conductors, the resistance of the

circuit must vary inversely as the square of the electromotive force employed. Now the resistance of the conductor varies inversely with its cross-section, and for a given length the cost of conductor will vary directly with its cross-section. Therefore we may put the law above stated into an expression involving dollars and cents, by saying that in conveying a given amount of energy a given distance with a given percentage of loss in the conductors, the cost of these conductors will vary inversely as the square of the electromotive force employed. In distributing energy at 200 volts, the cost of copper in the circuits is but one-fourth the cost in distributing energy at 100 volts; at 500 volts the cost is but one twenty-fifth, and at 1000 volts, one one-hundredth as much as in distributing at 100 volts. In the illustration of the two one-horse-power motors above referred to, the cost of conductors for the second is 1 per cent. of the cost of conductors for the first.

In the above statement and illustrations of the law governing the relation of electromotive force employed and the cost of conductors, no account is taken of insulation. The statements made are based simply upon the cost of bare copper. In practice, the commercial application of this law is limited by the fact that almost any pressure calls for some insulation, and the higher the pressure the better the quality and the greater the cost of such insulation. The law governing variation in the cost of insulation as potential is increased, therefore opposes, to a greater or less extent, the law governing the variation in the investments for copper, as above stated; nevertheless, it is true, that economy in investment for conductors imperatively demands high potential. Bearing this in mind, and recalling the fact that in distributing power we may vary either the potential or the current, it is not difficult to understand why the development of electrical apparatus has been along two opposite lines. Dynamos may be designed to deliver either a constant potential and a variable current or a constant current and a variable potential. Corresponding with these two classes of machines, we have in the systems of conductors distributing energy also two classes, namely: first, Series circuits, and second, Parallel or Multiple Arc circuits. We have also systems involving combinations of the series and parallel methods.

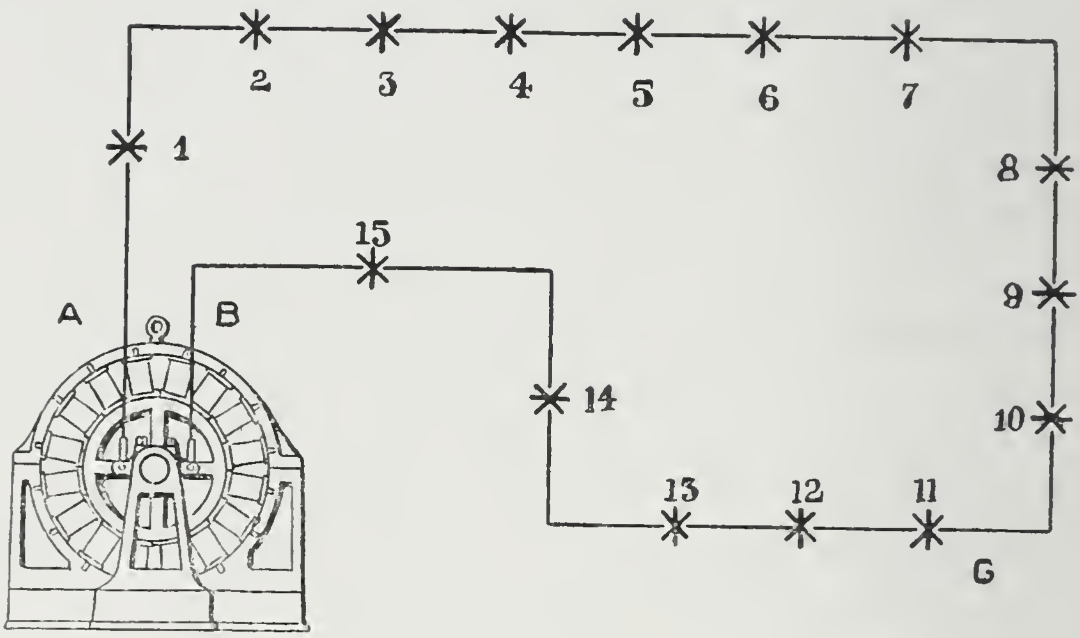
The series system is usually adopted in supplying arc-light circuits. In this system, if the circuit be perfectly insulated, there is but one path for the current from the positive to the negative terminal of the dynamo. That path leads through each of the lamps placed one after another in the circuit, that is, from the positive terminal of the dynamo the current passes along the conductor to the first lamp; passing through the mechanism of this lamp and forcing its way across the small clearance between the two carbons, at which point the arc is formed and the light is developed, it leaves this lamp and traverses another section of conductor to the second lamp in the series. Passing through the second lamp in the same manner, it traverses another section of conductor to the third lamp and so on, finally returning to the negative terminal of the dynamo. The difference of potential between the terminals of each lamp, that is, between the point where the current enters the lamp and the point where it leaves, is about 50 volts; therefore, at each lamp a drop of 50 volts occurs in the electrical pressure. The strength of the current measured at any two points in the circuit is the same, and is equal to about 10 amperes. The difference of potential delivered by the machine is varied in such a way as to be proportional at all times to the number of lamps burning. If ten lamps are burning, the difference of potential at the terminals of the dynamo is 500 volts. If 20 lamps are burning, the difference of potential at the terminals of the dynamo is 1000 volts. This arrangement is illustrated in Fig. 1, which shows 15 lamps in the circuit.

Let the wire A be connected to the positive terminal of the dynamo, and the wire B to the negative terminal. A current of 10 amperes is assumed to flow through the lamps in their order, that is, through 1, 2, 3, etc., returning after traversing all of the lamps to the negative terminal by way of the wire B. If we measure the difference of potential existing between B and the wire A at the positive terminal of the dynamo, we shall find 750 volts. Measuring the difference of potential between B and the conductor between the first and second lamp, we shall find 700 volts; measuring the difference of potential between B and the conductor between the second and third lamp, we shall find 650

volts, and so on, the difference of potential decreasing 50 volts as each lamp in the circuit is passed. In such a circuit as this the number of lamps does not usually exceed 60, which corresponds with a difference of potential of about 3000 volts.

In multiple arc or parallel distribution, there are two or more paths for the current from the positive to the negative terminal of the dynamo. This arrangement is illustrated in Fig. 2. As is seen upon inspection of this figure the circuits bear a general resemblance to a ladder, the main conductors being represented by the frame of the ladder, while the short conductors in which are

Fig. 1.



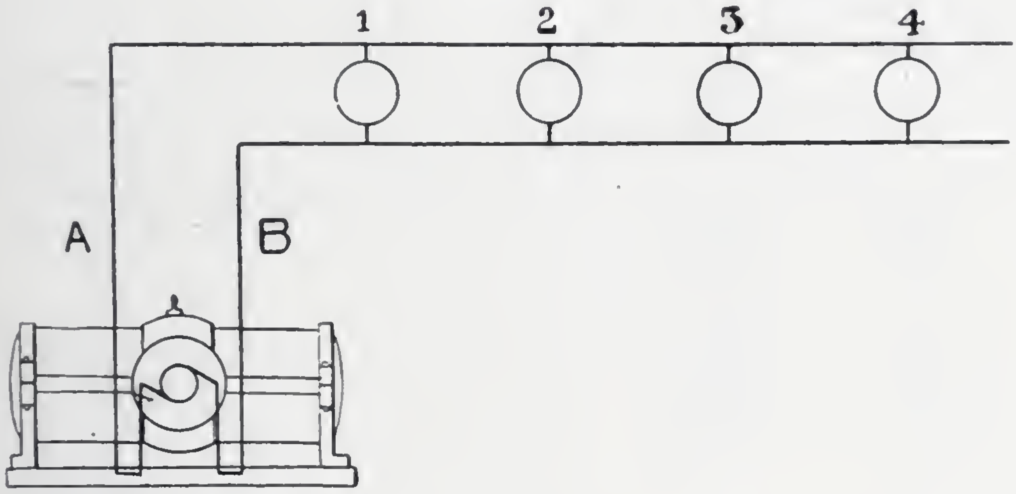
placed the lamps, or motors are represented by the rounds. In this system the dynamo delivers a constant potential and a variable current. A constant difference of potential being maintained between the two main wires of the circuit the current will of course vary as the lamps are turned on or off. Referring to the figure the large wires *A* and *B* represent respectively the two sides of the main circuit. Between these main wires incandescent lamps are shown at 1, 2, 3, etc. The dynamo is so constructed as to automatically maintain a constant difference of potential between the mains *A* and *B*.

If all the lamps are turned off the entire circuit is interrupted and no current flows. If the lamp at 1 be turned on, the others being left as before, a certain amount of current sufficient to supply

this lamp will flow along the conductor *A*, through the lamp at 1 and back to the dynamo by way of the conductor *B*. The amount of current which this lamp will take is of course determined by its resistance and the difference of potential applied to its terminals. Now suppose that the lamp at 2 be turned on. Twice as much current will flow in the conductors *A* and *B* as before, but the first lamp will be in no way affected. In like manner the lamps at 3, 4, etc., may be turned on or off, that is, they may be cut into the circuit or cut out without affecting their neighbors.

A moment's thought reveals the reason underlying the universal practice of employing parallel systems of distribution for interior lighting. Each lamp must be absolutely independent so

FIG. 2.



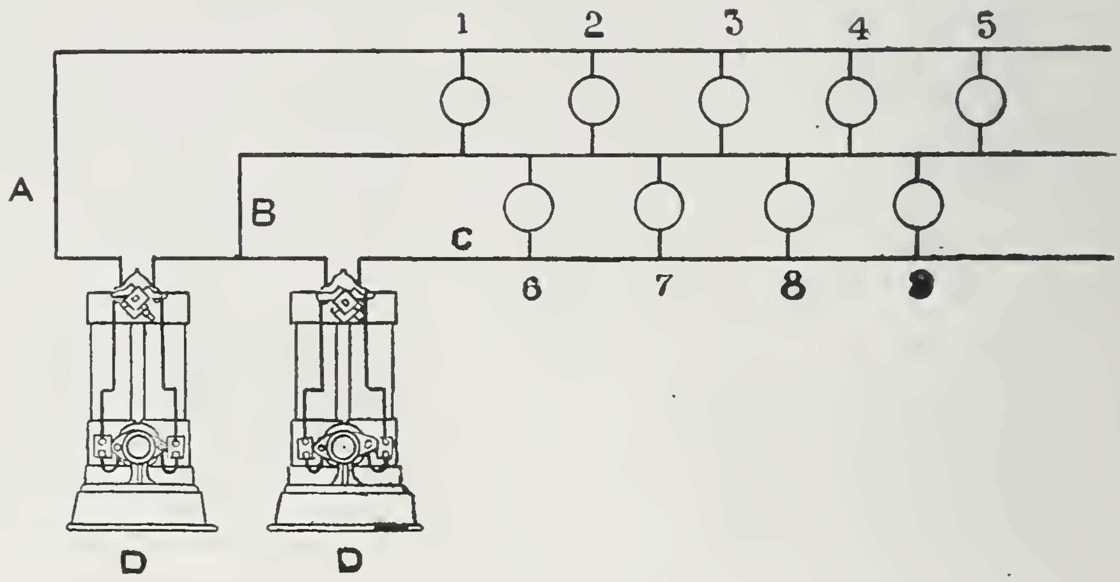
that it may be turned on or off as needed without affecting the others. Arrangements accomplishing this have been devised for series systems and are commonly used on arc-light circuits, but these devices involve an amount of additional mechanism, an uncertainty in their action and in many cases a loss of energy which are not allowable in a commercially operative system of inside lighting.

A modification of the parallel system is effected by substituting the earth or ground return for one of the main metallic conductors, that is, for one side of the frame of the ladder. This is the arrangement usually employed in the street car service already so extensively adopted in this country. An approximately constant

difference of potential between the overhead conductor and the earth is maintained, and the motors propelling the cars are connected in parallel to the circuit thus formed. Commonly the rails are used for the return circuit, special precautions being observed to insure metallic connection between adjacent rails, but of course this side of the circuit is very thoroughly grounded and is properly described as an earth return. The difference of potential usually employed in these street railway systems in America is about 500 volts.

Multiple series systems are combinations of the series and the parallel systems of distribution. A notable illustration is found

FIG. 3.



in the three-wire system extensively used in this country by the Edison Company, and is illustrated in Fig. 3. In this arrangement two dynamos, *D* and *D′*, are so connected as to form an electrical unit, that is, they must be run together and constitute practically one machine. Three conductors *A*, *B*, and *C*, distinguished respectively, as the positive wire, the balancing wire, and the negative wire, are used. As shown in the figure the positive terminal of the dynamo *D* is connected to the positive wire *A*. The negative terminal of this dynamo and the positive terminal of *D′* are connected to the balancing wire *B*, and the negative terminal of the dynamo *D′* is connected with the negative wire of the system. Lamps are shown at 1, 2, 3, etc.

If the number of lamps burning in each of the two branches of the circuit, that is, between *A* and *B*, and between *B* and *C* is the same, no current flows in that part of the balancing wire which lies between the lamp 1 and the dynamos. The current leaving the positive terminal of the dynamo *D* passes along the conductor *A* through the lamps 1, 2, 3, etc., through those short portions of the conductor *B* lying between the terminals of these lamps and those of the other branch of the circuit, then through the lamps 6, 7, 8, etc., then back by way of the conductor *C* to the negative terminal of the dynamo *D′*.

Now suppose that five lamps connected between the conductors *A*, *B*, and *C* are burning, while between the conductors *B* and *C*, but four lamps are in circuit. Current sufficient to supply five lamps will flow along the positive wire *A* and through the five lamps to the balancing wire *B*. Four-fifths of this current will flow thence through the lamps between *B* and *C* to the negative wire *C*, but the balance of the current, that which has flowed through the fifth lamp in the upper branch of the system, will return to the dynamos by way of the balancing wire B.

If five lamps were burning between *B* and *C* while but four lamps were in circuit between *A* and *B*, the current in *B* would flow away from the dynamo through the fifth lamp and return to the negative terminal of the dynamo *D′* by way of the negative wire *C*. This, then, illustrates the function of the balancing wire. It is not needed so long as equal numbers of lamps are burning in the two branches of the circuit, but when the number burning in one branch exceeds the number in circuit in the other branch the balancing wire carries a current proportional to the difference in the number of lamps in circuit in the two branches.

The purpose of this arrangement is to effect economy in copper. As we have seen, in lighting a given number of lamps located at a given distance from the dynamo with a certain percentage of loss of energy in the conductors, if 200 volts be used, but one-fourth the amount of copper is needed that would be needed were the potential limited to 100 volts. It has been found that the highest pressure that it is practicable to apply to the terminals of a single filament incandescent lamp is about 110 volts. Experience seems

to have established this limit for the present. For two-wire systems of distribution in which the lamps are electrically connected with the dynamo, therefore, common practice has fixed the limiting pressure at this figure. The three-wire system doubles this pressure, as measured between the outside, that is, between the positive and negative wires of the system. Doubling the pressure, if no third wire were necessary, would, as before stated, divide the necessary copper investment by four, but since the balancing wire is needed to take care of the system in case the number of lamps burning in one branch exceeds the number burning in the other, the cost of copper for a three-wire system as described, assuming that the balancing wire is of the same cross-section as each of the other wires, is to the cost of the two-wire system as 3 is to 8.

Other multiple series systems, known as four-wire and five-wire systems, have been devised. These are similar in principle to the three-wire system already described, and as their commercial adoption up to date is very limited no further reference to them need here be made.

This completes our discussion of the three sub-classes in methods of distribution. As before stated this classification depends upon the methods of running the circuit, and each of these three subclasses is applicable to each of two great methods of supply. The first of these two great classes is that method in which there is direct electrical connection between the generator and the lamp or motor; the second is that method of supply in which the energy from the dynamo is not delivered directly to the lamp or motor, being modified in its characteristics of potential and quantity by the interposition of the transformer or converter. In the first of these classes the transformer is absent, in the second it is present.

A few words in explanation of the transformer. The armature of every dynamo delivers an alternating current, that is, a current whose direction considered with reference to any wire in the armature is reversed many times per minute. The commutator is a device to which the wires of the armature are connected and upon which rest metallic or carbon brushes which are joined with the external circuit. This commutator is usually placed upon the

armature shaft and is so arranged as to collect the impulses of current delivered by the armature and deliver them to the external circuit rectified, that is, all flowing in one direction. Such a current as now flows in the external circuit is commonly called a direct or continuous current.

If, instead of using a commutator we simply mount upon the shaft two metallic rings connected with the ends of the armature circuit the alternating current delivered by the armature is collected and is delivered to the external circuit as alternating current. In our college laboratories many of you have seen an experiment something like the following:

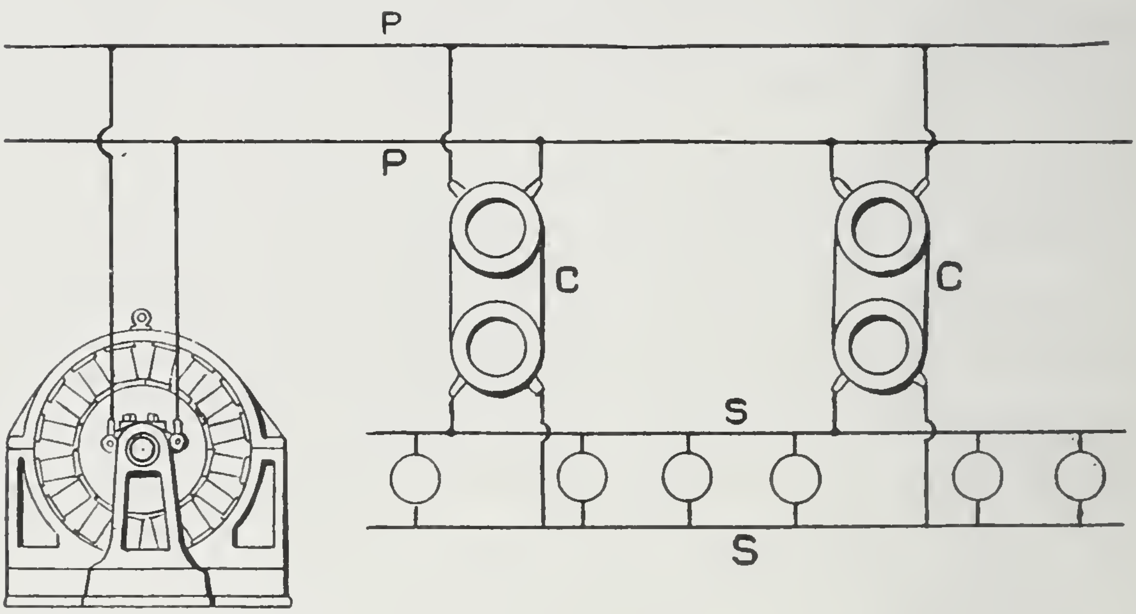
Two wires are placed in close proximity to each other throughout a considerable portion of their length. One of these wires is connected with a battery or other source of electric energy. The other wire is connected to the terminals of a galvanometer or other indicating instrument. When the circuit of the first wire is made or broken, the galvanometer shows that a current flows momentarily in the second wire. This is an ordinary illustration of the phenomenon of induction.

Any increase or decrease in the strength of the current flowing in the first wire causes current to flow in the second wire, the direction of the current in the second wire being always opposite to the direction of the current in the first wire. The two wires so arranged constitute a transformer or converter, though a very inefficient one. If, however, we take two long wires and wind them into coils, then place these coils near together and surround them with iron, we get a transformer which is able to transfer a very large proportion of the energy in the first wire to the second wire. This is the arrangement ordinarily adopted in commercial transformers. The primary coil is connected to the terminals of the dynamo, and receives, of course, an alternating current. The rapid reversals of this current in the primary cause powerful inductive actions upon the secondary, and an amount of energy almost equal to that in the primary wire appears in the secondary wire.

There is no electrical connection between the primary and secondary coils. The energy in the primary circuit develops mag-

netism in the iron of the converter. This magnetism, changing in sign and value very rapidly, induces an electromotive force in the secondary. The relation of electromotive force in the two coils will depend upon their respective lengths. If the primary and secondary are of the same length and we deliver to the primary an alternating difference of potential of 1000 volts, we get at the terminals of the secondary a difference of potential of 1000 volts, but if the primary is twenty times as long as the secondary and we deliver to it, as before, a difference of potential of 1000 volts, the difference of potential at the secondary terminals is 50 volts. When this circuit is closed through 20 50-volt lamps, a current of 20 amperes will flow at a pressure of 50 volts. This last arrangement is that usually adopted in incandescent lighting by

FIG. 4.



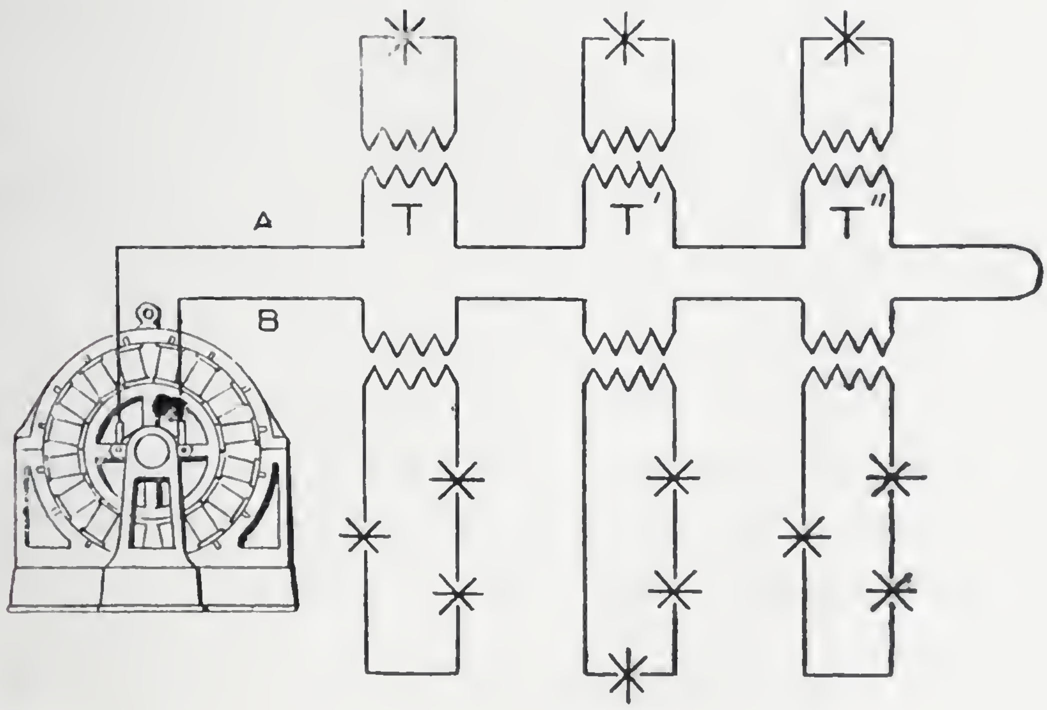
transformer systems in this country. The difference of potential in the primary circuit is twenty times as high as the difference of potential in the secondary circuits, while the current in the secondary circuit is twenty times as great as the current in the primary.

The object of this arrangement is of course economy in copper. Incidentally other advantages are obtained; first, entire separation of the inside circuits from the street mains; and second, ability to use what are commonly called low-voltage lamps, which are more efficient and durable than lamps requiring high pressures.

While the transformer system is equally applicable to series, parallel or multiple series, arrangements of circuits, its marked development thus far has been in connection with incandescent lighting and consequently with the parallel or multiple arc system of distribution. The ordinary arrangement of circuits is shown in Fig. 4. The wires *P* and *P* are supplied with alternating current from the dynamo. The difference of potential usually employed is 1000 volts. The secondary circuits of the transformers are connected to the wires *S* and *S* forming the mains of the secondary circuit. The difference of potential between these mains is 50 volts, and the incandescent lamps are connected in parallel to this circuit.

Within the last six months a series system employing transformers has appeared. In this, as in other series systems, the current is kept constant while the potential is varied with the number of lamps in use. This arrangement is illustrated in Fig. 5. The current leaving the positive terminal of the dynamo traverses the conductor *A* to the first transformer *T*; passing

FIG. 5.



through the primary coil of this transformer it traverses another section of conductor to the second transformer *T*′, and so on through the primaries of all the transformers in the circuit,

finally returning to the negative terminal of the dynamo by way of the wire *B*. The lamps are connected in the secondaries of these transformers. In some cases but one lamp is supplied by a transformer, in other cases three or five lamps are supplied. In this arrangement there is no electrical connection between the lamps and the dynamo. Perhaps the most striking feature of this system is the fact that the difference of potential in the circuit is not equal to fifty times the number of lamps, as is the case in direct supply. Without transformers the number of lamps that may be run in a series system is limited to about 60; with transformers a much greater number may be used without increasing the pressure in the line.

And now, where does the element of danger appear in these systems? Danger to life from the direct physiological action of energy in electric circuits can exist only in connection with circuits conveying currents of high potential. Anything that threatens property by causing fire, in a secondary sense, also threatens life, but, as far as danger to life from an accidental electric shock is concerned, it may be fairly said that low potentials are perfectly safe. But what is low potential and what is high potential?

It is impossible to draw a line through a certain point in a scale of ascending potentials and say that below this point no danger exists while above it all potentials are dangerous. Suppose that such a line be drawn at 300 volts. It is evident that there is no appreciable difference between the conditions existing in a circuit carrying 299 volts and another circuit carrying 301 volts, and it would be absurd to say that the former is safe while the latter is dangerous. Such a line of demarcation scientifically means nothing, nevertheless, for purposes of classification and to facilitate the drawing up of proper rules governing line construction and the general installation of plants, such a rule may be extremely useful.

It is not probable that electricians will ever agree as to where such a line as this may properly be drawn. Experiments of scientific value that might throw light upon the physiological effects of shocks from dynamo circuits are lacking. The best that can be done is to infer from the results of shocks accidentally

taken what potentials may, under certain circumstances, prove dangerous, to study as carefully as may be the conditions under which these accidents have occurred, and to determine so far as possible what precautions would have prevented their occurrence.

But inference from these cases of accidental contact with the circuits is very difficult. Testimony concerning the conditions under which the accident occurred is generally uncertain and often conflicting. In many cases, even the results are disputed, and the interests of the companies concerned or of those whose carelessness or ignorance may have caused the accident, sometimes result in concealment or obliteration of evidence that might perhaps have scientific value.

The results consequent upon a contact with high potential circuits are very largely dependent upon the manner in which contact is made. Every man carries around with him a certain amount of protection against the action of such a circuit. I refer of course to the resistance of the body. Here again we have a quantity that is very difficult to define. You will find printed statements of the resistance of a man's body from hand to hand, and these statements will vary all the way from 1800 to 50,000 ohms, and possibly between even wider limits. This wide variation in the results of measurements is largely if not entirely due to the fact that different methods of introducing the body into the circuit have been employed. In some cases the fingers have grasped metal contacts, and in others the hands have been immersed in solutions of high conductivity. The larger the surface in contact with the circuit the lower the resistance, and consequently since the resistance of the human body is very largely in the cuticle of the skin, any method that increases the area in actual contact with the circuit greatly diminishes the resistance of the body. It is not difficult to understand that a man firmly grasping the terminals of a dynamo may be killed by a pressure that would not seriously affect him had he simply touched the circuit with the tips of his fingers.

Last year the secretary of the National Electric Light Association instituted an inquiry into the subject of accidental contacts with high potential circuits. Letters were addressed to those

supposed to be familiar with the circumstances and results in a large number of cases, and many replies were received from men who had taken shocks, or, in those cases in which the accidents had proved fatal, from others who had investigated the circumstances.

The replies are interesting as showing the manner in which accidental shocks are ordinarily received, and they also illustrate the fact that a shock from a relatively low potential may in some cases result fatally, while shocks from much greater potentials often produce no serious effect.

From an abstract of the letters referred to, I note that of 36 cases of shock from arc-light circuits, 18 were from hand to hand. None of these shocks were fatal. 14 were from hand to feet, of which 3 were fatal. One shock of 1250 volts from forehead to right hand was not fatal. One of 2250 volts from elbow to feet was not fatal. One shock of 3000 volts from hand to opposite knee was fatal. One shock of 1500 volts from hand to side over heart was fatal. The 18 non-fatal shocks received from hand to hand were from circuits carrying potentials ranging from 1000 to 2500 volts. The man receiving the current between hand and side over heart was killed by 1500 volts. 19 men receiving shocks from higher potentials from hand to hand or from hand to feet were not injured.

It is evident that a great deal will depend upon the manner in which contact is made with the circuit.

Another influence modifying results in these cases is found in differences in constitution or strength of those receiving the shock. A shock that would not seriously affect a man may seriously or fatally injure a child. It is also probable that differences in temperament or nervous organization tend to vary the results. The entire subject of the physiological effect of shock is a very difficult one, and thus far the amount of reliable and scientifically valuable data is extremely limited.

Practically, however, it is not difficult to say which of the several systems in common commercial use are dangerous, and which are not. It is not a question of absolute but of comparative danger. No one will claim that the potential of 100 volts

which is extensively used in lighting large buildings by isolated plants can under ordinary conditions cause fatal shock. Probably few will deny that the 3000 volts of an arc-light circuit are dangerous, and should be surrounded with special precautions. Between these limits lie systems employing 300, 500, 1000 and 2000 volts, and other potentials.

A few moments must suffice to point out where the element of danger exists in each of the great commercial systems of distribution. This danger is of two kinds: first, danger of physiological shock, and second, danger of causing fires.

A person receives a shock by coming in contact with an electric circuit in such a way as to cause a part of the current to pass through his body. This may be done in either of two ways: First, by putting the person in contact with two points in a circuit, these points being charged with different potentials, as, for example, when a man grasps the positive terminal of a dynamo with one hand and the negative terminal with the other. Of, course, a contact of this description can be made accidentally by none except those engaged in operating a plant, or in doing construction work upon the circuits. If lines be properly insulated, and dynamos and other station apparatus reasonably well protected, the chance of accidents of this description, even to employees, is extremely remote. Another way in which a person may become connected into the circuit results from, what is technically known as a ground.

In describing the series system, I have said that in such a system, if the circuit be properly insulated, there is but one path for the current from the positive to the negative terminal of the dynamo. But absolutely perfect insulation is unknown. We must remember that at every point in a circuit conveying electricity a certain potential or electrical pressure exists. Between that point and every other point in the circuit which is at a different potential, there exists what may be called a state of strain tending to force the current from the point of higher to the point of lower potential. To prevent this the circuit must be thoroughly insulated, that is, it must be surrounded with some element or substance offering a high resistance to the passage of the electric current.

Referring again to Fig. 1, suppose that the wire at G is not so insulated, and suppose that another wire falls over the circuit at this point in such a way as to connect it with the earth. If the circuit between G and the dynamo is perfectly insulated, no current will flow. But suppose that while the circuit is grounded at G, a man comes in contact with an exposed part of the circuit in the lamp 1. Current will pass through him to the ground, thence to the wire which has fallen across the circuit, and thence back to the circuit at G. The shock will be proportional to the number of lamps between the point where he has made contact with the circuit and the point where a ground exists. In this case it will be due to a potential of about 500 volts.

If, instead of touching the circuit at 1, a man makes a contact between the lamp 15 and the dynamo, the shock which he will receive will be due to a potential of 250 volts. The chance of accident to the public resulting from grounded circuits is greater than the chance of accident resulting from actual contact with two points in the metallic circuit, but you will note that two things must happen before even such an accident as this can occur. First, the circuit must be grounded; and second, the man must come in contact with another point in the circuit. Instead of an actual metallic connection to earth, such as I have assumed, a considerable number of points of low resistance in the insulation will produce an equivalent condition of affairs.

Evidently if the circuit be so constructed and maintained as to avoid a ground, no such danger can exist. The first precautions that should be observed relate, then, to the construction of the circuit, and, in the case of aerial conductors, at least, they involve both mechanical and electrical features. In the first place, due regard should be had to such mechanical considerations as govern the construction of a bridge. The conductor should be so securely supported as to make sure that it will not break and fall into the street. The supports should be properly spaced, and should be well stayed against forces due to wind-pressure, unequal lengths of span or change in the direction of the conductors. In calculating the mechanical strains upon a suspended conductor, a large factor of safety should be allowed. In the second place the conductor,

if high potential is employed, should be thoroughly insulated with an efficient and durable material, except in the case of long distance transmission of power across the country, when in certain cases the insulation even of high potential lines may be dispensed with.

The electrical engineer has a great advantage over the mechanical engineer in the use of safety devices. A boiler may develop a weak point without giving any external sign of the coming explosion, but the electric circuit generally gives warning of the deterioration of its insulation. Even in those cases where a circuit is suddenly grounded through accident to the insulation, those in charge of the installation may, if they choose, be promptly informed of the occurrence, and they will, in nearly every case that can be imagined, have abundant time to repair the damage before any serious consequences can result.

In the case of the parallel systems of distribution, and in the case of multiple series systems as well, the conditions under which a shock may be obtained are very similar to those described in the case of the series system. One difference, however, is, that in case one side of the circuit be grounded, contact with the other side of the circuit, at any point, will result in a shock due to the full difference of potential of the circuit. As above shown, a shock resulting in this way from contact with the series circuit may be due to an extremely small or to a very great difference of potential, depending upon the resistance of the circuit between the ground and the point of accidental contact. But not so in the parallel system. Here, if one side be grounded, the full difference of potential supplied by the dynamo will exist between the other side of the circuit and the earth.

In the case of the single overhead conductor, extensively used in street-car service in this country, one side of the circuit, as has been said, is permanently grounded. The difference of potential existing between the overhead conductor and the earth in this system is usually about 500 volts. Contact with any point on the overhead conductor, unless the person making contact is insulated from the earth, will result in a shock due to 500 volts. In the case of these conductors, then, since no protection is afforded

by insulation of the other side of the circuit, it is especially important that the overhead wire be kept well out of reach, and so guarded that no other wires can possibly fall across it. In this country, telephone circuits ordinarily use the earth return, consequently, the contact of a telephone wire with the overhead conductor in such a street railway system, will, unless special precautions be taken, at least result in burning out telephones, and may cause serious shocks. It should not be difficult, however, to adopt such safety devices as would result in opening the circuit of any telephone line that may come in contact with the overhead conductor.

As to the high potential alternating-current systems of distribution the primary wires, that is, those wires which are charged with the high potential, are confined to the streets where the lines should be constructed in accordance with sound mechanical principles. They should be kept far out of reach of the public. They should be kept thoroughly insulated throughout their entire length with a satisfactory insulating material. The house-circuits are of low potential, 50 volts, and are entirely separated from the high potential of the primary circuits. Under but one combination of conditions can the primary potential enter the house-circuits. Those conditions are: the breaking down of the insulation between the primary and secondary coils, a ground on the street circuit, and a contact with the secondary circuit by a person making at the time of touching the circuit a good earth-connection. This chance is extremely remote. If not absolutely zero it is certain that proper precautions will make it a vanishing quantity.

If it be desirable, however, even this possibility of accident may be removed by any one of several safety devices. The secondary circuit may be grounded or the secondary coil may be surrounded by a metallic sheath connected to the earth, or other plans may be adopted.

Fires may be caused by electric circuits in various ways. The more common are two: *First,* suppose that we have two wires with a certain difference of potential existing between them, strung along the surface of a wooden partition or perhaps in a moulding. Suppose that in some way the wooden partition or moulding be-

comes wet. Unless waterproof insulation be used the moist surface of the board will form a more or less efficient conductor and current will flow across from the positive to the negative wire. The current forcing its way along the surface of the board develops heat. The board becomes charred and after a time perhaps we have a small blaze, which may become a large one. The danger is of course greater in the case of a high potential than in the case of a low potential circuit.

Second. A contact becomes overheated by an excess of current. Suppose that we have a fuse block or branch block in which the metallic contacts are not sufficiently heavy to carry the current, and suppose that the metallic contacts are mounted upon wood. The metal becoming excessively heated by the passage of a current too large for it begins to char the wood. The chances are that as the wood is charred and worn away, the resistance of the contact at this point in the circuit will increase, the heating effect will become still greater and perhaps sufficient heat will be developed to cause a fire.

Danger in this direction is greater in the case of circuits carrying large currents. You will remember that for a given amount of energy we may have a high potential with a small current, or we may have a low potential with a large current. It appears that a high potential tends to cause fires in one way while a large current involves a corresponding risk, arising in a slightly different manner.

A moment's thought demonstrates that neither of these dangers can exist where proper materials are used and where a reasonable amount of common sense is displayed. High potential circuits should not be allowed to lie against the surface of a wooden partition or floor, and cut-out blocks should be of porcelain or other non-inflammable substance and not of wood.

The one sufficient answer to all that may be said concerning the danger of electric circuits is that with proper construction this danger, although it cannot be reduced absolutely to zero, can be made very small. As far as the general public is concerned the element of danger is far less than is attendant upon the use of gas and steam. As to the risk incurred by the attendants of the gen-

erating station or those who are employed in maintaining the circuits, even that may be made slight. Pre-supposing a fair amount of intelligence and care on the part of those who do this work that risk will almost disappear.

The present agitation of this subject will undoubtedly tend to greater care in the construction and operation of plants. A certain amount of supervision in the way of general regulation imposed by the State, and intelligently directed by proper State authorities would meet the approval of all responsible companies engaged in the electrical industries. Whether or not the time is ripe for such regulation and supervision I will not presume to say. One thing is certain, that is, such regulation should aim to improve apparatus and to reduce to the farthest possible degree the risk necessarily attendant upon the utilization of large power. Whether directed by individuals, or companies, or the State, its purpose should be to secure proper construction, the use of proper materials and the exercise of proper supervision in the operation of plants. Interested parties in one, or two States have already attempted to secure legislation prohibiting potentials in excess of a certain value. To adopt such restrictions would be to cripple in infancy that industry which already promises to be the giant of this age. It would be exactly on a par with the statute that should decree that no buildings of more than one story in height should be built, for the reason that architects sometimes make mistakes and contractors occasionally use poor material. But there is little chance that such legislation will be adopted in any of our States. The people are interested in the development of this great science which has already done so much for their convenience and comfort, and which promises such wonderful results in the future.

Discussion.

George H. Payne: I am sorry Mr. Stillwell said nothing about underground electricity. That is one of the additional safeguards.

B. Speer: I should like to ask one question about something you referred to here with reference to the potential at the terminals of such a converter as you have described, which is supplying

three lamps. What would be the difference of potential at the two terminals of this converter?

L. B. STILLWELL: The difference of potential would be 50 volts, with a current of 30 amperes.

B. SPEER: On the same circuit?

L. B. STILLWELL: Exactly.

B. SPEER: Then in your diagram these are not meant to be the same circuit?

L. B. STILLWELL: This diagram, marked Fig. 5, represents one circuit.

B. SPEER: The same circuit cannot, of course, carry a circuit of 10 amperes and 30 amperes.

L. B. STILLWELL: The function of the one-arc light converter is in connection with these circuits. In some cases inside, and street lamps are supplied from the same circuits, the converter being used in the case of inside lights only.

B. SPEER: Do you make a converter which will supply a lamp on the same circuit as the single lamp?

L. B. STILLWELL: Yes. But this kind of a system is designed for use especially in large cities where the object is to use as large a generator as possible, with a limited pressure, say 2000 volts.

B. SPEER: You spoke of the number of "watts" in the primary and secondary circuits as the same. That is, of course, theoretical?

L. B. STILLWELL: Yes. You refer to loss in the conversion. That loss is dependent, of course, upon the construction of the converter. There are all kinds of converters. Some of them have a considerable loss, but a great many have very small losses. The latest converter I have seen tested showed a loss of a little less than 2 per cent., with secondary open circuited. It has not been tested at full load. The loss at full load would not be in excess of 4 per cent.

In reply to Mr. Payne's question: I did not speak of the problem of underground circuits, or the arrangement of underground circuits, for the reason that in our cities, except the very large ones, that is still a question fòr the future. There is no intrinsic reason why underground circuits should be safer than

overhead circuits, if the latter are properly constructed. For the great majority of American towns the overhead construction will, for many years I am afraid, still be necessary. As fast as these towns become densely populated cities, it will be possible to adopt the underground construction. The question is simply one of dollars and cents. The underground work will cost at least several times as much as the overhead construction. The underground construction is going on in New York now very successfully and it is the method usually employed in the large cities abroad. The problems in electrical construction underground are not very different from those in the overhead work. There is, of course, greater difficulty in insulating the circuits from the earth; better insulation and more of it must be used.

W. Thaw: Have I not heard of the use of hollow copper cylinders one within another, in London? There is in this case very little insulation.

L. B. Stillwell: I think you refer to the new station of the London Electrical Supply Company, which is at Deptford. The system employed by that company, or rather, I should say, the system which they propose to use, for I do not think it is yet in operation, is, as you say, one of concentric tubes, the outer tube having through its entire length and separating it from the inner tube a heavy layer of insulation. The tubes are made in sections and the connections are made by a special arrangement somewhat similar to the screw-thread used in water-pipes, with allowance for expansion.

W. Thaw: When they take the current off at a station, where do they take it from?

L. B. Stillwell: The proposition has been made to use at Deptford 10,000 volts pressure. That would be carried to sub-stations in the city. The centre of the district which the company proposes to light is about five miles from their station. At each of the sub-stations there are very large transformers to be used to reduce the potential from 10,000 to 2000 volts. The current would have to go through the outer tube to one terminal of the transformer and through the inner conductor to the other terminal.

A. E. Hunt: Speaking of the percentage of loss in the con-

verters, I would like to ask a question. Do you compare the percentage of loss actually in the dynamo or in the work that the dynamo will do like horse-power, with the work which the steam horse-power will give. For instance, you have your formula as so many watts divided by 746 giving such and such horse-power. How closely can you make your horse-power, or what factor do you use to indicate the horse-power to run that dynamo?

L. B. STILLWELL: As I understand, you mean, "What is the efficiency of the dynamo?" That is the same as with the converters; it is variable. Many arc-light dynamos are very inefficient. The reason is, in some instances, due to very high internal resistance. Some of these dynamos have very low efficiency, I think not exceeding 40 or 50 per cent.

W. THAW: Is it the fact that you can approach the best economy with large ampere and low voltage?

L. B. STILLWELL: No, I think there is no difference. I should say further that those arc-machines to which I have referred are the worst made, the least efficient. A good many dynamos are constructed giving an efficiency at least as high as 90 per cent., and I know of claims in excess of that. But I do not believe many of such claims are warranted by the facts. But there are many dynamos very efficient. I know of a number of tests showing from 85 to 90 per cent.

A. E. HUNT: Steadily?

L. B. STILLWELL: Yes, sir, under full load.

A. E. HUNT: Steadily, with the full load within 10 per cent.?

L. B. STILLWELL: Yes, running under full load and at their maximum temperature.

B. SPEER: What is the efficiency for the Westinghouse dynamos for arc-lights? Can you tell us?

L. B. STILLWELL: Yes, sir, I can. There was a test made about two weeks ago. Two dynamos were tested at the same time, one running 60 laps and the other 120. The actual candle-power of the lamps was not measured, but they were compared with ordinary arc-lights apparently giving at least as much light. The engine was indicated and the number of lamps in the circuit counted; the current flowing through the circuit and the difference of potentials at the terminals of single lamps were measured.

From the measurement of the difference of potential at the terminals of several lamps the total difference of potential in the circuit was estimated and multiplied by the product of the current, giving approximately the energy of the circuit. We had for comparison the indicator on the engine. The results of that test showed surprisingly high efficiency for the arc-light dynamo. The maximum figures were obtained at full load and were about 88 or 89 per cent., and at the half load, as I remember it, the efficiency was 70 per cent. or in that neighborhood.

W. L. Scaife: Did the experiments you mention indicate which current, alternate or direct, was the most dangerous?

L. B. Stillwell: I did not refer to the answers received by the secretary of the Electric Light Association in so far as they dealt with shocks from alternate currents. But he had nineteen cases reported of shocks received from an alternate current at high potential. In seventeen of these cases the shock was taken from hand to hand. Such shocks, if the circuit is well taken care of, can only be received by linemen. They only can get such a contact. Not one of these cases was fatal. In another case the shock was received from the knuckle to the palm of the hand and in another case from hand to arm. Neither was fatal.

W. Thaw then recited an instance of where a current was discovered coming down a wooden telegraph pole on Smithfield Street some weeks since, with apparently no conductor near. Mr. Stillwell replied that he could give no explanation of the occurrence if there was no wire near. The nearest wire was reported as thirty yards off, and it could not possibly have been received from it.

After passing a vote of thanks to Mr. Stillwell for his paper, the Society adjourned.

S. M. Wickersham,
Secretary.

April 15th, 1890.

Society met at 8.15 p.m.

President W. L. Scaife in the chair.

Vice-President, Phineas Barnes; Director, W. G. Wilkins, and 30 members present.

The following applicants for membership were duly elected: W. A. Giles, William Morgan, James Ritchie, Frederick Schaeffer, Daniel Ashworth, Charles F. Scott; after which W. C. Quincy gave the following talk on

B. & O. R. R. ENGINEERING BEFORE AND AFTER THE WAR.

The notice does not state exactly what I propose to do this evening. I am hardly able to go back forty years and relate anything about railroad building. My purpose is to read extracts from reports of others prior to forty years ago, and to give you a few personal reminiscences of my connection with the Baltimore and Ohio Railroad during its construction and the trying periods of the civil war.

Most of my railroad papers in connection with early days in the service of the Baltimore and Ohio Railroad are packed away at my former home in Ohio. I am therefore unable to refer to them to-night. I have a few personal telegrams and some of the early reports of the Baltimore and Ohio Railroad, also copies of the annual reports during my thirty years in its service. I think extracts read from these reports and a talk upon personal reminiscences will interest you more than an original paper.

Let me first carry you back to the days of the pioneers in this enterprise, and read from the first annual report of Mr. P. E. Thomas, President, October 1, 1827. The report consists of but two pages, and shows that Mr. Thomas had a high appreciation of engineers. "The directors have also deemed it of primary importance, in the first instance, to secure the services of an engineer upon whose talents and skill they may safely rely. It is their desire, not less their duty, to obtain the best professional aid the country will afford, and they will spare no efforts to engage a superintendent of the highest character. The government of the United States, justly appreciating the importance of this enterprise, have extended to it a most liberal patronage. Several able and efficient members of the topographical corps have been detached to the service of the company. In conclusion, the board feel a

high satisfaction in stating, as a result of all the information and experience they have yet acquired, that their confidence in the practicability of the railroad remains unabated."

I will also read from the second report of Mr. Thomas, for 1828: "It is obvious also that with the prospect, almost arising to a certainty, of the greater amounts of trade being directed eastward, at least for a series of years, their engineers could not, with any regard to the economical application of motive power, admit on this part of the route *the least descent in its progress westward*, and since any greater elevation than that on which the road commences would but have increased the obstacle presented by the steep and rugged hillsides bounding the Patapsco, to say nothing of the disadvantages which would have resulted in passing the numerous broad and deep ravines, they were constrained to *sustain a level* at greater variance with the natural surface of the ground than will again be necessary."

The Board of Engineers state: "The natural surface in the immediate vicinity of the routes is generally firm and well adapted to the reception and support of a road. Quagmires are nowhere to be met with, muddy grounds seldom occur, and in no instance do they present any serious impediments in the way of easy construction. The hills are nowhere so abrupt and elevated as to render tunnelling necessary, although any route leading through them must maintain *a serpentine* course in order to preserve *a level.*"

The Board of Engineers go on to say: "The subject of horizontal curvatures or deviations from a right line, so far as may be inferred from a perusal of numerous treatises on railroads, seems never to have engaged the attention of engineers in due proportion to its importance. In vain have we searched in treatises of the description just mentioned for rules and computations of easy application in tracing the route of a railroad in situations where curves are unavoidable."

I will also read from the report of Mr. Benjamin H. Latrobe, Chief Engineer of Location, in 1836: "Upon the Baltimore and Ohio Railroad the curvatures were so great, being a radius of 400, and in one instance of 318 feet, that many doubted the practica-

bility of running locomotive engines upon it. However, in consequence of the perseverance of the President and directors of the company, an engine was placed upon the road in the year 1831 that could traverse all the curves with facility, and convey 15 tons at a speed of 15 miles an hour, *on a level*."

From the same report I read: "Locomotive engines, such as have already been described in this and preceding reports, continue to be fabricated in the shops of the Baltimore and Ohio Railroad Company, by the contractors, and the performance of these engines has hitherto been highly satisfactory. Few trials of their extreme tractile power have been made since last year; such, however, as have been made, together with such as occasionally occur in the business of the road, may be briefly related. On the 12th of September last, being the occasion of the anniversary of the battle of North Point, several volunteer companies from this city and the counties adjacent, amounting in all to 900 or 1000 citizen soldiers, were conveyed to Washington and back by *four* locomotive engines, one of which conveyed about 300 troops with their arms and accoutrements. Now, although the full power of the engines were by no means brought into play on this memorable occasion, yet the result had a very impressive effect upon the many thousands who witnessed it, and who were thus furnished with ocular proof of the new and immense facilities created by railroads and locomotive engines upon them, in the transit of persons and property, and in fact of whole armies and their accompaniments. The trains here mentioned advanced to Washington in the morning and returned the evening of the same day, and as the return was effected with speed and safety, *notwithstanding it was dark*, a confirmation was had of the practicability and facility of locomotive travel *by night* as well as by day."

During the month of March, 1849, through the influence of Mr. Benjamin Deford, a personal friend, and a director of the Baltimore and Ohio Railroad, I obtained employment as chainman in the engineer corps. In those days boys of my age were paid from $1.50 to $2.00 per week. When Mr Latrobe told me my pay would be $1 per day I felt that I was assnred, not only occupation, but a fortune. I reported for duty to Mr. Charles P.

Manning, at Cumberland, Md., and was engaged upon location until the summer of 1850. I was appointed assistant, and subsequently, resident engineer of construction. We boarded for several months with Mr. Henry Church. He was an English soldier of the Revolutionary War, was taken prisoner, and settled at Cappofork, Va. He was then 101 years old. For his kind attention to us a flag station was established on his farm and called "Old Hundred."

In this connection I will relate an incident which occurred at the time we were building the road. I asked the old gentleman the price of timber. He said, so much. "Mr. Church," I replied, "that is entirely too much." He answered, "It will be worth more than that to me twenty years from now."

There were many tunnels, and my connection with them was as assistant engineer in the building of four, engineer of ten, and the arching of six; twenty in all. The building and the arching of some of the tunnels was difficult and hazardous, Kingwood and Board Tree tunnels particularly so. I was not connected with the former tunnel, but will read an interesting report from Mr. Bollman, then Master of Road in 1856.

"The great difficulty attending the arching of this tunnel has been owing principally to the nature of the material or rock through which it passed. By exposure to the atmosphere it rapidly decomposed, which caused it frequently to fall in such large masses as to block up the tunnel for a considerable distance, to the depth of 8 or ten feet, besides upon the timbering, which was first introduced to prevent accidents to the trains by falls from the roof, such large quantities of loose rock had accumulated, that when the timbers were removed to make space for the arch, it frequently by its great weight, caused the timbers to give way and crushed all beneath it. It was, therefore, necessary for the protection of the workmen to perform this part of the work with extreme caution, and considerable skill, energy and expense were requisite to accomplish it. The unfinished part fortunately has a roof of better material, and with the exception of having to take down a part of it to allow sufficient room for turning the arch, all difficulties and dangers are now removed. I indicated that a part

of the arching was composed of cast-iron, to which some objection may be raised on account of its tendency to deterioration from rust, etc. And to remove all apprehensions on that point, I would say that that important consideration was not lost sight of, but that a plan was adopted and fully carried out, in the execution of the work which will, in case the iron arch should be destroyed, fully sustain the roof for all time to come. This plan simply consisted of forming a rough arch of sandstone, which was convenient to the tunnel and well adapted to the purpose, immediately upon the top of the iron arch of a most substantial character. This auxiliary arch of stone did not, as some might suppose, add materially to the cost, for it must be borne in mind that the space between the part of the main arch and roof of the tunnel must in all cases be well packed with hard and durable stone, and, therefore, the stone arch only occupies the space of so much packing, and costs but a fraction more in the aggregate. A brick arch would have cost less than an iron one, and would have been preferred under ordinary circumstances, but the difficulties we had to contend with drove us in a measure to the adoption of the latter, for without it I believe certain parts of the tunnel could not have been arched, unless indeed we had disregarded the lives of the workmen and security of the trains as they passed through.

"Each section of the iron arch is composed of two segments, each of which is nearly equal to a quadrant, 3 feet wide and $\frac{3}{4}$ of an inch thick, with two ribs each $\frac{3}{4}$ inch thick and 6 inches deep, attached to the soffit, and when in position the heels rest on the top of the side walls, and are secured at the crown, where they abut by iron bolts. The iron arch was well protected by paint and pitch to prevent as far as possible the action of rust. The facility with which these sections were placed in their position in the tunnel, and the security they gave to the workmen, was truly astonishing. By means of an ingeniously contrived hoisting car, the segments were carried and set up in the tunnel in the short time of from five to ten minutes to each section, equal to three lineal feet of arch, and immediately thereafter props, to prevent heavy falls from the roof, were rested upon them, which made all comparatively safe, until the packing was completed.

"After a careful inspection of this interesting piece of work, I think the Board will agree with me in saying that it stands unsurpassed for durability, and also, when all the difficulties attending its progress are carefully and impartially weighed, to conclude that, although the expenditure appears large, it could not have been done for less."

I will also read from the report of 1852:

"The same expedient of a line over the hill at Board Tree will be resorted to as at the Kingwood tunnel, viz., the passage over the natural surface of the ridge by gradients of steep inclination. The summit over this tunnel is 300 feet high, being 80 feet greater than that of the Kingwood tunnel, yet the inclines are so located as to give planes of much less acclivity, there being no ascent greater than 6 feet in the 100, instead of upwards of 10 *feet in the hundred*, as at the Kingwood ridge. A locomotive will, for this reason, perform twice as much work as upon the latter grade, and there will be no risk of the train sliding backwards with locked wheels, as occasionally happened on that grade when the rails were slippery."

Is it a matter of surprise that when witnessing for the first time the locomotives ascending these grades Mr. Latrobe, the chief engineer, raised his hands and exclaimed, "Wonderful! wonderful! wonderful?"

The annual reports of the Maintenance of Way department from 1858 to 1868 were written by me, and I will refer to and use them. My first work connected with the arching of tunnels was at Boardtree tunnel, and our experience was similar to that at Kingwood, but the mass of loose material on top the timbers was much greater, being from 10 to 26 feet. We worked in from the sides between the timbers with about eight gangs of miners, removing this mass, and when the timbers were taken down the section of the tunnel was 18 feet wide and 30 to 50 feet in height. Heavy falls occurred, at great risk to the lives of the men. The roof and sides were in many places beyond the reach of poles, and continual falls of rock delayed the progress of the work. Each mason and bricklayer had a watchman to warn them of falls. If

my memory serves me, over 30 men were killed and 300 injured in the arching of this and the Kingwood tunnel.

During the years 1866–7, in addition to other duties, I had charge of the building of second track and three tunnels at the Point of Rocks. I quote from the President for 1866:

"The protracted litigation and delay in building the road in the early history of the company, caused by the conflicting claims of the Chesapeake and Ohio Canal Company for the right of way through the narrow and difficult passes of the upper and lower Point of Rocks, will be remembered. The same lofty and precipitous mountains of rocks again presented, on the north side, their barriers to the construction of the second track, whilst the Chesapeake and Ohio Canal interposed between the single track and the Potomac river. As the line could be materially improved, heavy curves being thus avoided, and the continuous double track secured, it was determined to construct a tunnel 800 feet in length at the lower, and two tunnels about 700 feet in length at the upper Point of Rocks.

"The rock proved peculiarly flinty and hard, but by working large forces night and day from four different points one-half of the first tunnel was completed and the work on the approaches and much difficult side-cutting near the canal for the upper tunnels were accomplished, whilst navigation was suspended in the winter months. Similar though less serious difficulties were encountered on the upper Potomac.

"In consequence of the limited margin for the road in many portions of that valley it became necessary, in order to secure the width of the road-bed required for the second track, either to fill out and make embankments in the river, or to cut into the rocky mountain sides. The latter plan, though more difficult and costly, was adopted, and thus a first-class, secure and permanent line was obtained.

"Notwithstanding the heavy and difficult character of the work, 70 miles of superior second track were constructed during the year."

My report is mainly to the same effect. Forces worked day and night. At times the progress was only 4 feet per week; for many

of the heading holes it was requisite to sharpen over *one hundred and ten* drills to bore *thirty* inches. I remember the foreman who had charge of the work, James Collins, a very faithful fellow. It was his delight whenever I came along to call my attention to some of his men. There was a very large man among them, named Enos McDonald; he called him "Big Enos;" and Patsy Joyce and others. I cautioned him to be very careful and not obstruct the track; his reply was: "No danger; if a rock gets on the track as big as a shanty, big Enos and Patsy Joyce could get it out of the way without delay to trains."

A few days after this conversation Collins met me on the train. He appeared all broken up, and I asked him the matter. He replied: "A liquor shanty has been built near the end of the tunnel; many of the men are drunk, and I cannot get any work out of them." I expressed a wish that some night the men would get drunk, tear the shanty down and destroy the liquor. He said: "Do you wish that?" I replied, "Yes." "When will you be back?" "The day after to-morrow."

On my return Collins met me on the train and asked "if I had heard of the misfortune." I replied "No." I supposed some of his men had been killed. He said: "Some of my men got drunk and tore that shanty down and destroyed the liquor." Adding, "I am investigating it, and as soon as I find who they were I will tell you." I did not ask him to press his investigations. I felt that if big Enos, Patsy Joyce and others were capable of removing a rock as big as a shanty in a few minutes, they could certainly remove the shanty itself during a night.

I will mention that the Chesapeake and Ohio canal at the time of the construction of the road had the prior right of way; its boundary was distinctly marked by iron pins in the side of the bluffs, 40, 50, 60, 90 feet above the railroad. The canal company brought suit against the railroad company, and it was argued by the best lawyers of that day. The canal company suggested to the railroad company "as the railroad would not amount to anything, they had better take the money they had and help build the canal." The president of the railroad company wrote a letter suggesting that "both the canal and the railroad should be

built to the point of conflict, and after it was demonstrated which served the public best, the other should be abandoned." The matter was finally adjusted by the railroad company building the canal, and also the railroad along this narrow passage. The legislature of the State of Maryland, during its last session, 1889, authorized the sale of the canal to a railroad company.

During the first year of the war I prepared a chronological table of the leading events of the war, as connected with the destruction of the road by fire and by flood, and handed it to President Garrett. He instructed me to include it in the annual reports, and refers to it in his report as follows:

"The report of the maintenance of way department furnishes many interesting facts regarding the repeated destruction and restoration of the road and works of the company. The chronological table in the report of that department embraces full historical information of the varied losses and operations of the company in connection with reconstruction, to which the Board invites special attention."

I will read some of the most important events, and relate personal reminiscences connected with them. "On the night of the 18th of April, 1861, the detachment of the United States regulars guarding the arsenal at Harper's Ferry, after setting fire to the buildings, evacuated that point. At 10 P.M., Virginia State troops marched in and took possession, placing a guard of infantry and artillery upon the bridge. The trains continued to run with many interruptions until May 25, 1861, at which time the large rock at Point of Rocks, supported by masonry, was undermined and thrown upon the track. On the following day, Buffalo Creek bridges, Nos 3 and 4, were burned. This destruction was the precursor of losses by fire and flood which followed in rapid succession. They will be noticed in chronological order." After the occupation of Harper's Ferry, in April, 1861, through trains were run until the 25th of May. The Union forces, under General Butler, were stationed at the Relay House; at Harper's Ferry were found the forces of Stonewall Jackson; at Cumberland, Union forces; and at Grafton, Virginia state troops. For a period of nearly two months trains were run through the lines of

both armies. I had frequent interviews, in regard to matters connected with the operations of the road, with "Stonewall" Jackson, Colonel Ashby, and other officers, during their first occupancy of the line, and afterwards with many of the generals of the Federal army. I made the acquaintance of nearly all the generals who were along the line of the Baltimore and Ohio Railroad except, perhaps, "General Result."

I will never forget the exciting and stirring scenes of the night of the 18th of April, 1861, and many subsequent events of the war. I left Baltimore on the morning train, and reached Harper's Ferry at 12 o'clock, noon. I noticed two gentlemen get off the train at Harper's Ferry; and a large crowd of persons assembled on the platform said to them, "Well, how is it?" They replied, "The State of Virginia has passed the ordinance of secession, and troops are now marching to capture Harper's Ferry." One of these gentlemen was Colonel Barbour, who had charge of the arsenal. I thought it important to remain and watch matters. There was much excitement during the afternoon; speech-making, drinking, and threats to burn the bridge. About 2 o'clock, desiring to inform President Garrett, I went to the telegraph office. I was greatly surprised to find the first soldier of the war guarding it. I said, "Well, soldier, where do you come from?" The soldier, with much more dignity than I had shown, replied, "What do you want, sir?" I replied, "I want to go into the telegraph office." He answered, "The telegraph office belongs to the State of Virginia." I said, "Does it? I supposed it belonged to the Baltimore and Ohio Railroad Company." I sent to the next telegraph station a message to Baltimore, advising the condition of affairs, and to send me a special engine and telegraph car, and on arrival to attach the wires about a mile below Harper's Ferry. After a few hours, the engine and car came over the bridge. The conductor informed me they had left the telegraph car on the other side of the river. The excitement abated towards night, but as a precautionary measure I had a large number of barrels filled with water placed upon the bridge. I also placed additional watchmen on the bridge. Conflicting reports that 500 or 600 soldiers were within a mile of Harper's Ferry were contradicted

by others that there were none between there and Winchester. I said to the engineer, "I will go into the car and lie down; If anything happens, waken me, and we will go down to the telegraph car and telegraph to Baltimore." I had been in the car but a moment when I heard shots on the bridge. The Virginia troops were firing at Jones's men as they were retreating. I hurried to the front of the car and called to the watchmen to look out for the bridge; as I did so, the engineer started his engine; I climbed over the tender and on to the engine; by the time I succeeded in doing so we were about half a mile below Harper's Ferry. I called to the engineer, "Stop, where are you going?" He replied, "You told me if anything happened we would go to Sandy Hook and telegraph." "But," said I, "We do not know that anything has happened." He said, "Did you not hear the shots on the bridge?" "Yes, but we do not know that anything has happened. Go back where you started from, and I will ascertain what to telegraph about." He backed the engine, and by the time we reached the bridge the whole place was illuminated, and explosions were frequent. Lieutenant Jones, in his retreat, had set fire to the buildings, and trains of powder laid in them caused the explosions. Every one was endeavoring to save the guns from the arsenal. Almost every man had one or more muskets. I remember seeing one of my foremen, Mike Dunn; he also had a musket. He came to me, presented, and said, "Mr. Quincy, I am here." It was a pity to dampen the ardor of this valiant man, but I told him to put the gun away and to get a bucket of water, he could do more good with it. Just then, one of the watchmen came and reported that men had gone on the bridge to burn it. I started after them, and found them with kindling wood preparing to fire the bridge. I asked them what they were going to do. They answered, "Burn the bridge." I asked, why? They answered, "There is a regiment of soldiers coming up from Baltimore, and we are not ready to meet them." I told them I was familiar with the movement of troops on the line, and I knew there was not a soldier between Harper's Ferry and Baltimore. They asked me who I was, and how I came to know so much. I told them who I was; they then said (and I remember it was the first fright I

had), "Have you not been here to-night with an engine and car, and have you not helped Jones and his troops to escape into Maryland? If it had not been for you we would have captured them." I realized my unfortunate position, and at once answered that there had not been a soldier on the car. They then asked me what I was doing there with the engine and car. I did not care to give this information, but I again assured them that there had not been a soldier on the car; and added, "If it will satisfy you I will remain until to-morrow, and if, upon investigation, you find there has been a soldier on the car, or *en route* from Baltimore, punish me." One of them said, "Cap, that's fair enough." And under promise not to leave until after I reported the next day they spared the bridge as well as myself.

I recrossed the bridge to Harper's Ferry. The telegraph operator came to tell me the guard had left his office. I instructed him to go back and put out the lights and I would follow him. I telegraphed to the next stations east and west the condition of affairs, directed all trains stopped until they heard from me, and failing to do so, not to permit any train to come to Harper's Ferry without first ascertaining that it was safe to do so. I also telegraphed my wife, "Do not be alarmed about me, I am O. K." Going out of the telegraph office I found a company of artillery placing a twelve-pound brass cannon upon one end of the bridge, and also a company of infantry. The officer in command said, "Now men, take your position here and if a train approaches give a signal to halt. If they do not halt instantly, fire into them." I said, "I have just heard the orders you have given these men, sir, and if carried out you may kill some one, and regret having done so. It will be impossible if a train approaches to stop it instantly. If you want it stopped at this point, you must send a guard some distance up the road to signal it, and after doing so, if they pass the bridge fire into them. I will go up with the guard and show them how to signal. But you will not be bothered with trains for I have stopped them." He asked, "Who are you, and what right have you to stop trains?" I informed him who I was, and arranged to go up with the guard and show them how to signal trains. Soon after the operator came to

me and said, "Mr. Quincy, Martinsburg telegraphs that fast stock train left before receiving your telegram." This filled me with apprehension because they were already suspicious that I had carried Jones' troops over the bridge, and as I had said all trains had been stopped, if a train approached they would fire into it. I found the officer and explained, telling him it was not a troop train. The train approached slowly. The trainmen supposed the bridge was on fire. After examination the officer permitted it to proceed.

I remained at Harper's Ferry until the next day and then reported to the captain. He said they had investigated the matter and had no charges against me. In this connection I will read, from *Battles and Leaders of the Civil War*, by Lieutenant Jones; "As the evening advanced nearer and nearer came the troops from Halltown and finally, shortly after 9 P.M. when they had advanced to within a mile, the torch was applied; but very few arms were saved, for the constantly recurring explosions kept the crowd back. I have heard that within a few minutes after my command had crossed the Potomac to the Maryland side of the river, a train was heard starting off for Baltimore and that it was assumed by the Virginia troops and their officers that my command had been taken off by that train and that consequently pursuit was useless."

Whilst we were running trains across the bridge, petards were placed between the braces to destroy it. They were made of cast-iron pipe about 2 inches diameter, about 2 feet long, the ends stopped with wrought-iron plugs; into these a piece of safety fuse was inserted. I had the watchman secure one which I afterwards took to Baltimore and had considerable amusement at the expense of the railroad officials who were afraid to have it in the building.

In January, 1862, General Lander was appointed to take command of the forces at Hancock and asked Mr. Garrett if an officer of the road would accompany him. Mr. Garrett told him he thought I would. The next day we went by rail to Frederick and thence by stage to Hagerstown, intending to remain there over night. The General was a brave soldier, an excellent man, but at times a little profane. About 11 o'clock he sent for me and said "Quincy they are fighting like h--l at Hancock." "Well," said I, "What have I to

do with it?" He asked, "will you go there with me to-night?" I replied, "I started from Baltimore to go with you." We left about midnight. I said, "you will have work to do at Hancock to-morrow; sleep and I will keep guard." He placed a brace of pistols on the front seat of the carriage; I called him during the night; he was alarmed and seized the pistols. I said, "there is no danger; I believe I am freezing." He took a flask from his satchel and told me to drink freely. I believe that little "speak-easy" saved my life. We reached Hancock about 5 o'clock the next morning and found great demoralization. We walked along the streets in the dark until we found a soldier with a gun in front of military headquarters. On entering, one of the officers, supposing I was a member of the General's staff, said to me, "I do not like the position of my guns near the church;" I replied, "I will look at them in the morning." After we reached headquarters, we obtained a bed by the General ordering out two officers who were occupying it. Referring to this event General Imboden in *Battles and Leaders of Civil War*, writes as follows: "Another force moved from Winchester and on the 4th of January the town of Bath was occupied after being abandoned by a body of Union troops, composed of cavalry, infantry and artillery. Jackson followed the retreating troops to the river and promptly bombarded Hancock, Md., without, however, securing a surrender. The weather was inclement and intensely cold. Many in Jackson's command were opposed to the expedition, but in that terrible winter, march and exposure, Jackson endured all that any private was exposed to."

About the 1st of March, 1862, Gen. Lander, then at Pawpaw, telegraphed me to come there. I went and he told me his plans to make an advance on Winchester and desired the bridge at Sleepy creek trestled. He asked how long it would take. I replied, "it depends altogether on military protection, interruptions, etc." "Well," he said, "if you will let me over in two days, I will give you the best watch and chain that can be bought. But if you don't let me over in two days, I will hang you." I replied "I do not want a watch and to hang me would be an ungrateful return for my trip to Hancock with you." We built the bridge, but he never crossed it, as he died the following day.

Washouts by flood or burnouts were frequent during the war. The trestling in the Potomac was difficult, the river bed being very irregular, and much difference in the length of the trestle legs in same bent. After a washout, two or three days would elapse before a boat would live in the current, and then it was necessary to spike railroad bars to the trestle legs to sink them. The chronological records show that in March, 1862, orders were given to repair and re-open the road and on the 10th it rained hard and the river continued too full and the current too swift to accomplish much at the main bridge at Harper's Ferry. On the 12th work was resumed and pressed with all possible energy until the night of the 18th, when the first locomotive for nine months crossed over into Harper's Ferry. A few days thereafter the road was opened for traffic. Every bridge from Harper's Ferry to Cumberland had been destroyed, all the water stations, and 42 miles of main track, the iron rails carried away, so that we had a difficult task to restore the road for traffic.

On its completion, I received the following telegram from President Garrett; "Camden Station, March 31, 1862. W. C. Quincy, I congratulate you. The achievements of the Road Department are such as to attract great attention and command the highest satisfaction of the Company. Your personal energy, and persistent and successful efforts are fully appreciated."

Mr. Prescott Smith, the master of transportation, who was a little more enthusiastic, telegraphed: "Consider yourself saluted by 3000 cheers and 5000 guns for your successful efforts in restoring the road. I congratulate you. You have achieved much and shall receive the credit due you."

On the 29th July, 1863, we were laying track beyond the Opequan Bridge, 18 miles west of Harper's Ferry. (I was admirably served by my telegraph operators. They, during the trying periods of the war, kept me fully informed). About six o'clock in the evening, the operator came and told me "to look out for squalls," that the commanding General had sent an order to the cavalry guarding us to get over into Maryland as quick as possible, as there were 800 men within five miles to capture the railroad men." I walked to Martinsburg, two and a half miles, found

the carpenters who were building the bridge at that place at supper; told them it was likely Mosby would be there *the next day* and that we would fall back to Harper's Ferry. We walked back to Opequan and thence by train to Harper's Ferry, returning the next day with military guard. We found it was a false alarm, and finished track laying. A few days after I returned to Baltimore and went into Mr. Garrett's office. He welcomed me kindly, was glad we had finished the work so soon, but added it would have been completed a day earlier if it had not been for your unfortunate retreat from Opequan. Said I, " Mr. Garrett, we were left without military guard and I thought it proper to go back to the protection of the guns at Harper's Ferry. " Why," said he, " I was not at all alarmed." I replied, " I would not have been either in this office one hundred miles away, but it is altogether different being at the front and sleeping in an old car." He replied, " that does make a difference."

Referring again to the report, I find that on the 10th of April, 1864, the rivers and small streams were much swollen, but by constant vigilance at all the trestling, trains were worked through with but slight interruption until April 10th, when the Potomac river at Harper's Ferry became swollen to a great height with much drift running. The trestled spans as a precautionary measure were weighted with loaded cars upon them. At 11.40 P.M., the wide span, including the Winchester span thereupon was swept out, carrying with it the cars with which it was weighted. The river continued to rise; on the following day the current was so swift that it became evident that it would be impossible to cross even in boats for several days. There were at the time large bodies of troops on the line *en route* for the defense of Washington and extraordinary measures had to be determined upon in order to ensure their prompt transportation. Standing on the Maryland side, and looking over into Harper's Ferry, I could see troop trains extending far up the track. The river was running full of drift and everything was most discouraging. I telegraphed Mr. Garrett the condition of affairs, telling him the bridge had gone out, and as the troops were for the defense of Washington, he had better at once order them sent by the way of Pittsburg and the

Northern Central railroad. He replied, "I have your telegram. *I rely upon you to cross the troops.*" I showed it to the foremen and asked what we could do? They replied, "you know it is impossible to work in the river for three days." I asked Capt. Pengaskill, who had charge of the pontoon corps if he could furnish boats or any temporary expedient to cross the troops, I would furnish the men to do the work. He replied, "I have but one boat and it is impossible to do anything." I again telegraphed Mr. Garrett I was fearful he did not realize the situation, stating the condition of the river, the drift, etc., and urged him to order the troops via Pittsburg. He replied, "I repeat my first telegram. *I rely upon you to cross the troops;* they will not be ordered back." I walked out to the pier, and as I gazed wistfully at the river the thought occurred to me that the easiest solution of the matter would be to jump in and drown myself, but my life was saved by a little cast-iron washer. I noticed it on the pier and picking it up said to the foreman, "Have you a man who can throw this with a string attached over into Harper's Ferry?" He answered yes. We had every appliance that could be thought of from a spool of thread to a 6-inch cable, with all necessary blocks, tackle, etc. I ordered wire cables from Baltimore by special train which reached its destination on the morning of the 12th. Previous to its arrival a small line with weight attached had been thrown across the opening; by means of this larger lines each increasing in size were passed and repassed until a 5-inch cable was secured, upon which the wire ropes were taken over, and at 5 P.M. of the *same day* the passengers from delayed trains and regiments of troops were passed safely over an improvised suspension bridge. I telegraphed Mr. Garrett what I had done, and he answered, "*I was satisfied you would cross the troops.* The energy and zeal of the officers and men of your department are highly appreciated." I remember when I informed the foreman of bridges we would build a suspension bridge, he asked for the plan. I told him I had none but will guarantee if we get a line across to build one sufficient to carry the troops.

During the war many locomotives, cars, rails, track-fixtures and machinery were hauled by animal power over turnpike-roads from the line of the road to the railroads in Virginia. These locomo-

tives and cars were used to transport Johnson's troops to reinforce Beauregard at Bull's Run, and it will be remembered, their timely arrival caused the defeat of the Union armies.

I read sometime since, a report on this subject, which did not agree with my chronological table, and I wrote to an acquaintance in regard to it. He replied: "I have yours of the 19th. When I went to Winchester, in June, 1861, I found on the Winchester and Potomac railroad one hundred and sixty Baltimore and Ohio box- and gondola-cars, which I hauled from Winchester to Strasburg. I hauled, from Martinsburg to Strasburg, ten locomotives and all of the machinery in the shops at Martinsburg. Then I hauled from the road-crossing, about a mile east of Duffield, over to Halltown five locomotives, which I found standing on the siding at Duffield. I took these over the Winchester and Potomac road to Winchester, and hauled them to Strasburg. The old engine '32' was left at Harper's Ferry. I rebuilt the bridges between Harper's Ferry and Halltown, and took it to Winchester where I left it. At the time of the evacuation of Manasses, I had two Baltimore and Ohio engines and one Manasses Gap engine, and six or eight box-cars at Strasburg. I was at that time military-railroad superintendent at Manasses under General Johnson, and I ordered the three locomotives and the six or eight box-cars sent to Mt. Jackson by rail, and then hauled them down the valley from Mt. Jackson to Staunton, fifty miles, put them on the Chesapeake and Ohio railroad, and took them to Richmond. All of the hauling was done by horses over the wagon-roads, using from twenty-two to forty horses to an engine, according to the size. These are the facts of the case, all of which are verified by my records, which I still have. All the rails taken up, were hauled to Winchester and Strasburg; some used to build railroad from Manasses to Centerville, others rolled into armor-plates at Richmond and put on the Merrimac."

March 30, 1865, the mail-train from Baltimore to Cumberland was captured. As guerrilla forces were reported near the road in many places, I took charge of the movement of the train. We reached Greenspring Run about dark, and, as three thousand Union troops were there stationed and a like number at the next station, I felt that we had passed the danger-point, but midway at

Dan's Run a rail had been taken up and the train left the track. On looking ont, I saw guerrillas with pistols in their hands approaching the train. I had an order in my pocket, from Secretary Stanton, giving me temporary charge of the Winchester railroad for the government, and my first thought was this order. I tore it up and threw the pieces out of the window. These guerrillas boarded the train, and their manner of pressing a revolver against my face had a most impressive effect. It was my custom to carry about eighty dollars in gold for use in case of capture. I had put this, excepting five or six dollars, in my boot, and handed over my pocket-book. Another presented his revolver and demanded my watch. I replied, "They have already taken all I have; ask them to divide with you." He took my hat, and left me with my watch in my pocket. They ordered all the men "to leave the train and come *this way*." It occurred to me I would *go the other way*, and I got off the far side of the train and, by keeping in the ditch close to the cut, was soon out of sight. I was startled by discovering a man standing near the track, and, supposing he was on guard and would take me prisoner, I approached in the most humble manner, and said: "My dear sir, can you tell me where I can find shelter? I was on the train, they have taken my money and my hat, and I do not know what to do, or where to go." He replied, "*They took all I had, too.*" He ran away before I did. I said, "Come with me and I will take care of you," telling him I had a perfect knowledge of the country, etc. We walked to Greenspring Run, distant three miles, and the next morning at daylight I returned and cleared the wreck.

In conclusion, I will state that, in February, 1861, I was directed by President Garrett to take President Lincoln in my car to Washington, but a change in the programme left me to take Mrs. Lincoln, Colonel Ellsworth and others safely to Washington instead. April 15th, 1865, I accompanied General Grant to Washington, and, on the 21st of same month, upon the invitation of the Secretary of War, I accompanied the honored remains of the late President Abraham Lincoln *en route* to Springfield, Illinois.

Society adjourned at 10.05 P.M.

S. M. WICKERSHAM,
Secretary.

May 25th, 1890.

Society met at 8.15 o'clock P.M. at the rooms.

Present, President W. L. Scaife; Vice-President, P. Barnes; Directors, M. J. Becker, W. G. Wilkins; Secretary *pro tem.*, F. C. Phillips, and 33 members.

The Board presented the applications of the following gentlemen for membership, who were duly elected: H. J. Lewis, J. H. Barrett, R. R. Singer, Hakon Hammer.

The Committee on Affiliation made the following report, which was adopted:

REPORT OF COMMITTEE ON AFFILIATION.

Gentlemen: Your Committee appointed to confer with the American Society of Civil Engineers with a view to establishing a closer relationship between the various engineering associations of the United States, respectfully submit the following report:

A considerable number of engineering societies now exist in the different States, each possessing local peculiarities and satisfying local wants. Being organized to accomplish different aims under different circumstances, they possess a vitality and an individuality—and, therefore, a value—which could not be increased by any other single plan of organization known to your Committee. For any one society to attempt to form a "protectorate" over these associations, or to turn them into "branches" governed by the same rules, would be, in our opinion, either unsuccessful or disastrous, as tending to check their natural birth and development.

We fully recognize the unfortunate fact that the isolation of these local societies is a direct loss to the engineering profession and to the country, whereas their successful co-operation would ultimately give an incalculable impetus to the engineering progress of the United States and of the world.

Engineering, in its various branches, is perhaps the most powerful factor in the material progress of this country, and yet engineers, as a body, have very little influence in national or state legislation, however worthy the object may be, principally because they lack the power due to concentrated aims and efforts.

The American Society deserves credit for attempting to increase its own usefulness and that of other engineering bodies throughout the United States; and in view of the foregoing remarks we would suggest the following general plan in reply to the inquiries of their Committee:

1st. That the American Society and other engineering associations of the country form a federation, which shall leave to each society its autonomy and individuality.

2d. This federation to be governed by a council, whose members shall be delegates from the constituent societies, chosen on a basis of numerical membership; but each society to have at least one representative.

3d. This federative council to possess powers delegated to it from time to time by the societies, such, for example, as the selection of local papers for its transactions; the determination of conditions of transfer of a member from one society to another; the interchange of published transactions; and the investigation and discussion of subjects of national importance.

The president and secretary of the American Society might occupy similar positions in the council, whose place of meeting, at stated periods, would naturally be New York.

By means of such a federation the American Society would preserve its present high standard of membership while gaining many new members and additional influence as the acknowledged head of a powerful, active and extremely useful federation of engineering societies of the United States.

W. L. Scaife,
Thomas P. Roberts,
John W. Langley,
Committee.

Pittsburg, May 20th, 1890.

After the report of the Committee on the Proposed Federation of American Societies was read,

Mr. Langley said: I may say just one word by way of explanation. The report of this Committee is only preliminary. In fact, it is necessarily not final, because the invitation of the American Society, under which this Committee was appointed,

looks to a conference in New York of representatives of various societies, and it is a part of the duty of this Committee, as originally appointed, to attend this conference.

The Library Committee reported that a series of the publications of the United States Coast and Geodetic Survey has been received from the Superintendent of the Coast Survey, Prof. T. C. Mendenhall.

On motion, the thanks of the Society were given to Prof. Mendendall for his attention to our interests.

M. J. Becker, before beginning the reading of his paper on the construction or replacing of one of the piers of the Steubenville bridge, said: I am really apprehensive that before I get through with the reading of this paper I shall be called to order by the chair for violating the first section of the By-Laws of this Society, which, if I recollect right, provides that the regular meetings of the Society shall be devoted to the reading and discussion of papers on scientific subjects.

Now, I may as well say right now that the text of this paper is not upon a scientific subject at all. It is simply the story of one of those occurrences which happen frequently in the practical execution of engineering works, and which lead in their correction to difficulties which very often are somewhat troublesome to overcome.

And yet these occurrences are in a measure useful because they teach us how not to do things, and it is simply with that view that I am induced to read this paper, and I wish you to simply consider it in the same light.

Mr. Becker then read the following paper:

A TEMPORARY BRIDGE SUPPORT.

The foundations for the piers of the channel span, and for the two piers east of the channel span, of the Ohio river bridge at Steubenville, Ohio, were laid in 1862 and 1863, and the masonry of these piers was completed in 1864.

The west abutment, a portion of the east abutment, and parts of the remaining piers had been built as early as 1855, but financial embarrassment compelled a suspension of the work until the re-

sumption in 1862, when such portions of the old masonry as were found in good condition were utilized and finished.

The bridge consists of eight spans, and its total length is 1910 feet. The three western spans are 210 feet each, the four eastern spans are 231 feet each, and between these two groups is the channel span of 320 feet length. The channel span is a so-called "through" span, the track resting on the lower chords of the trusses; all other spans are so-called "deck" spans, the track resting on the upper chords of the trusses, 90 feet above low water in the Ohio river.

The original superstructure of this bridge was of the well-known "Linville" type, named after J. H. Linville, C.E., of Philadelphia, who designed and built it. At the time of its completion, in 1865, it was the only iron railway bridge across any of the navigable tributaries of the Mississippi river, and it was the longest span iron-truss bridge ever attempted up to that time.

The foundations for the piers of this bridge consisted of ordinary timber platforms, composed of three or four courses, bolted together and sunk into pits excavated in the river-bed by dredging-machines. The sequel will show that this method is not to be recommended as an example for general observance. After the foundation pits had been excavated to their proper depths, the timber platforms were floated into position, secured by guide piles at the corners, and gradually lowered by the increasing weight of the masonry as it was laid on the platform, until they finally settled upon the bottom of the pits. It was very difficult to maintain a smooth and level surface at the bottom of these pits during the lowering of the platforms, the under-current washing out the shifting material in some places and depositing it in others, causing great inequality at the bottom, and preventing the platforms from finding uniform bearings.

This was especially the case with Pier No. 5, which is the pier between the two spans next east of the channel span.

When the foundation pit for this pier had been dredged out to its required depth, the platform, consisting of three courses of 12-inch pine timber and a top layer of 2½-inch plank, was floated into position, and gradually sunk by the increasing weight of the

masonry built upon it. It was not expected that the platform would at once come to a full bearing, and its slightly irregular settling during the laying of the first two or three courses of masonry created no surprise; but after the fifth course had been laid it was supposed that a firm bearing had been reached, and that no further settlement would take place. Levels were taken on top of this course, showing a depression of 7 inches at the up stream end of the pier as compared with the down stream end; and an average transverse depression along the east side of the pier of $1\frac{1}{2}$ inches.

The top of this course was then trimmed to a uniformly horizontal surface, and the masonry continued to the top finish, without signs of unequal settling. But just before the erection of the superstructure, it was discovered that the pier had suddenly settled westwardly, so as to show on its top a departure of about 22 inches from its normal longitudinal axis. This movement eliminated the batir on the west side of the pier entirely, and increased it on the east side from the original ratio of $\frac{1}{2}$ inch per foot to about 1 inch per foot. The question then arose whether it would be safe to place the iron superstructure upon this leaning pier. A careful examination found the masonry in perfect condition without a sign of fracture in the stone or of a rupture in the joints. It was evident that the west edge of the platform had at first lodged upon the slope of the pit and rested there until the pier was completed, when it started and settled to the bottom of the pit, carrying with it in its movement the body of the pier intact. There was still room enough on top of the pier for the support of the trusses, although the bed plates of the end posts of the eastern span came rather uncomfortably close to the edge of the coping.

After a short consultation it was decided to erect the superstructure upon the pier as it stood, protect its base with a large deposit of riprap; make regular periodical observations so as to detect any possible additional movement, and trust to luck for the rest.

The pier has stood firm and carried its load from that time until last fall, for a period of twenty-five years.

During the summer of 1888, the four eastern spans were taken down and replaced with a double track superstructure. It had

been decided to take down and rebuild the leaning pier at the same time, and it was the intention to accomplish this by placing the two spans adjacent to this pier upon false works simultaneously, and begin the removal of the pier just as soon as the track had been placed upon the false-works trestles, and the dismantling of the trusses had commenced. By working then vigorously day and night on the removal and rebuilding of the pier, we hoped to complete it in time for the reception of the new superstructure. Under favorable circumstances this could have been done, but, unfortunately, during the entire working season of that year, the Ohio river continued at such a high stage as to make it very hazardous, if not impossible, to undertake the task. Meantime all preparations had been made for the erection of the superstructure of the two spans; the false works had been placed in position, and it was decided not to delay or incur any risks upon this part of the work by waiting for a possible favorable opportunity to renew the pier. It became, therefore, necessary to provide for the removal and rebuilding of the pier by a different method.

After a careful consideration of all conditions, it was decided to erect the two spans and rest their adjoining ends upon the old pier, and after removal of the false works, build a strong temporary wooden trestle pier on the outside of and enclosing the leaning masonry pier; lift the ends of both spans of the superstructure clear of the masonry; remove the coping and some parts of the upper courses, place heavy plate girder beams on the temporary wooden trestle pier, introduce strong gridiron pedestals to carry the end posts of the trusses, and after placing cast-iron sand-boxes under the plate girders, where they rested upon the temporary trestle-pier, lower the two bridge spans and carry them upon these supports until a favorable condition of the river would permit us to remove and rebuild the defective pier.

This arrangement is fully shown on the accompanying plan and photographic view.

Two rows of piles were driven on each side of the pier, in the positions shown on the plan; there were 12 piles in each row, or 48 piles in all; they were fitted with strong wrought-iron points, so as to penetrate the riprap which had been placed around the pier

from time to time, and which had become very solid and compact. The piles were cut off at an elevation of 17 feet above low-water mark, double capped longitudinally, cross braced between the two adjacent rows, cross capped by notched timber ties to resist the thrust from the leaning trestle-posts, and two stories of ordinary trestles erected, the inner posts being perpendicular and the outer posts inclined; each story capped longitudinally and transversely, cross braced and bolted. On top of the upper longitudinal caps two solid timber platforms were laid, one on top of the other; on top of the upper platform were placed the sand boxes, which were filled with dry sand after the outflow holes had been closed with wooden plugs; the iron cover lids were placed on the tops of the sand boxes, and the four pairs of plate girders were then swung into position. These plate girders were built of sufficient strength to hold up the two adjacent ends of the two spans of the bridge and the live load passing over them, amounting in the aggregate to about 800 tons. During this operation, however, only one track was used over the bridge, although it was built and is now used as a double-track structure. The plate girders were made 50 feet long, which was longer than necessary for the purpose, but their flanges and webs had to be of such extra dimensions for this work as to correspond to the sizes of a 50-feet span under ordinary traffic, and they could, therefore, be used to good advantage elsewhere, after having served their purpose at the Steubenville bridge.

Meantime the two spans of the bridge had been resting upon the old pier, the coping of which had been partly removed at the time of the erection of the trusses, to make room for the four sets of gridiron pedestals, each composed of eight heavy 15-inch I-beams, connected together by top and bottom plates which had been placed under the end posts of the trusses to serve as copings; these gridiron pedestals were 9 feet long, reaching entirely across the two pairs of plate girders, and the trusses of the bridge rested upon them centrally.

The superstructure of the two spans, whose ends rested upon the gridiron pedestals placed on top of this pier, had been completed in November, 1888; the false works which had served in

their erection, were removed in December, 1888; the pile-driving for the temporary supports was commenced February 16th, 1889, and on April 1st, 1889, the trestles had been erected.

Before the plate girders could be swung into position, the masonry had to be removed as far down as the bottom of the girders; blocks of masonry, however, had to be left standing between the lines of girders to carry the bridge until the plate girders were placed in position. The cutting away of these blocks of masonry was a tedious and somewhat dangerous operation, and we felt quite relieved when the girders had been placed and wedged up under the gridirons so as to carry part of the load, and relieve the remaining blocks of masonry of part of the pressure. This was safely accomplished on June 4th, 1889.

All was now ready to dismantle the pier, but the stage of the river continued too high to admit of the adjustment of the tilted foundation platform, which we hoped to accomplish before starting the new masonry for the pier, and the work remained in this condition until August 6th, 1889, when the tearing down began, and on August 14th, the pier had been removed to the top of the fourth course from the bottom.

An examination of the foundation platform was then made by drilling through the remaining courses at ten points around the circumference of the pier to the top of the timber, when it was found that the western edge of the platform was five inches lower than the eastern edge. The lower four courses of masonry appeared in perfect condition, although, of course, inclined at the same angle as the platform.

The riprap around the pier was found to be very compact, and everything seemed to indicate that it would be safer to let the old platform and four lower courses of masonry remain, and build upon this thoroughly settled foundation, than to tear it all up and start a new one of similar kind, with a possibility of its settlement and a repetition of the former trouble.

Pile-driving for a new foundation was too risky on account of the liability of disturbing the trestle supports which now carried the bridge and traffic.

The new work was therefore started with the fifth course of

masonry, the top of which was trimmed to a level surface on September 5, 1889. On October 10th, the load was transferred from the girders to the completed masonry, and on November 20th, the last piece of coping was laid after the girders had been removed.

There are 860 cubic yards of masonry in the new pier above the fourth course.

The gridiron pedestals remain in the work; but they are concealed by the surrounding coping stone, and the spaces between the L-beams are filled up solid with concrete or Portland cement. The new masonry stands up well, and does not show the slightest indication of settlement.

Exclusive of the plate girders which are now in use elsewhere, this work cost $12,059.84. A good pile foundation under the original pier would have cost about $1500 more than the timber platform; but it would have saved the cost of the rebuilding, and spared us much trouble, anxiety and mortification.

Discussion.

Thomas P. Roberts: I will ask Mr. Becker if any borings were made to determine the depth to solid rock beneath the pier? During the years 1866 to '70, whilst in the government service on the Ohio river improvement, I had occasion frequently to pass under the bridge, and the "lean" of the pier was quite noticeable. Since that time I have frequently crossed the bridge on trains, making such observations as I could, and long ago came to the conclusion that the settling had ceased. I am, however, somewhat curious to learn the nature of the material under the foundations. From my experience in dredging and sounding on the river, I would expect to find in the channel, or mid-river point, in the neighborhood of Steubenville, a coarse gravel and boulder bottom, which is generally compact, and not to be disturbed, excepting by powerful currents. I am well aware that the construction of piers always causes local disturbances and increase of velocity in the current; but upon such a bottom, with ample riprap protection, there is not necessarily danger in pier construction.

M. J. Becker: There were no borings made, to my knowledge, at the time the bridge was built there in 1855, nor in 1862 when the

work was resumed. The indications were that no rock would be found at reasonable depth. In those days the foundations, by means of caissons and pneumatic processes, although perhaps known, were considered entirely too difficult to be warranted under the conditions and circumstances. The material at the bed of the river was, as Colonel Roberts says, composed of coarse gravel mixed with boulders, and quite uniform. It was considered a good foundation, and no doubt would have been a good foundation, if it had not been for the unfortunate lodgment of the corner or side of one of the platforms, leaving an unsupported space underneath, which, when the entire load came on at once, yielded, causing the whole pier above to settle down and tilt over on its side.

I think if the platform had sunk squarely and horizontally on its bottom, there would not have been any difficulty whatever. The other piers are built on similar foundations, and there has not been the slightest movement in any of them. Some of them have been there for 35 years.

WILLIAM THAW: Were they built recently for double track?

M. J. BECKER: They were built originally on a liberal scale for a single track, and there was no necessity to enlarge them excepting the T-walls on the abutments. With the exception of this masonry on the T-walls, no additional was required on the entire bridge.

THOMAS P. ROBERTS: Was there any coffer dam about the original excavating?

M. J. BECKER: No, sir. We simply rigged up a little arrangement around the platform, and pushed the masonry along rapidly so as to be practically above high water by the time we reached the second or third course.

THOMAS P. ROBERTS: There was some current there probably just about that time?

M. J. BECKER: Yes, sir; and for that reason we hastened the work as much as possible. We pushed it day and night, and we laid the two courses of masonry, I think, on the ordinary piers in a day or a day and a night, and on the larger channel piers in about two days, the idea being to get down to the bottom as rapidly as possible, and avoid the accumulation of material flowing in.

Thomas P. Roberts: They had some trouble at the Union bridge with the grillage foundations. These were floated into position at rather high water, and they could not keep them in line owing to the anchors dragging, etc. The piers are, therefore, built out of line. All of the bridges on the Monongahela river, built on that plan, have settled a little one way or the other. One pier of the Tenth Street bridge I notice has settled at one end about one foot. It seems to have gone down bodily, but no cracks have disturbed the integrity of the structure, and I presume the settling has stopped. I think, however, it is a defective plan of construction. It is economical, but it is only permissible for comparatively light structures where the material is coarse gravel or boulders, and where at no time the current is excessive.

W. C. Quincy: I have not had much experience of this kind. We had something like Mr. Becker's Steubenville experience on the Baltimore and Ohio road at Bellaire, at which the foundations were made in the same manner, but the settlement there was uniform. We did not have any trouble such as Mr. Becker refers to.

M. J. Becker: I will just say that the rebuilding of this bridge in 1862 and 1863 was done by Colonel James Andrews, of Pittsburg, who, later on, improved somewhat upon the method of foundations when he built the St. Louis bridge.

Thomas P. Roberts: In regard to the protection of ordinary bridge piers from erosion and undermining, it is my opinion that not enough attention has been paid to this detail by the engineers of our highway bridges constructed across the Allegheny and Monongahela rivers. These are navigable streams, and steamers "drawing all the water" must necessarily pass close to the rip-rapping. Under such circumstances there is a powerful "suck" or draught in the current which sometimes rolls away the stones, and certainly capable of washing out all the finer or "bonding" particles of sand between them. This process of washing out the sand intermixed with the riprap may, and does, sometimes extend to and beneath the foundations. Hence results the "squatting" or settlement of the whole mass in proportion to the percentage of solid matter lost. But as we must, from motives of economy, build bridges on this comparatively cheap plan of securing founda-

tions, I have thought it would be the part of wisdom to surround the foot of the slope of the riprap with a line of sheet piling of heavy oak plank, driven as close as possible, and cut off at least two, or perhaps three, feet below low-water mark, so that boats will not damage them. In addition to this precaution, if a foot or more of the bottom of the protection was well grouted, or, better, formed of concrete rammed down, and on top of this the largest kind of irregular-shaped stones, carefully laid, with interstices filled up with long stones, points up, that there would be little trouble. The riprapping of the Ninth Street bridge had to be renewed every few years. It seems to me that the plan I have suggested involves little expense, but the custom has been to dump rip-rap stone around piers with a rather vague idea of its utility. It has been found by experience that it is best not to put a floor in these cribs, but to leave them open so that they can fill the pockets from above, and the cribs will remain perpendicular. The United States engineers now generally build their cribs and ice-breakers without any floors.

W. G. Wilkins: I have had no experience on the Monongahela river, but I had on the Kiskiminetas, out on the Butler branch of the West Penn. We only went down four feet below the bed of the river, two feet of timber and two feet of stone. A great many people prophesied that that foundation would wash out. It went through the flood of the same year it was built; it went through the Johnstown flood, when all the bridges were washed out above and below, and it is standing yet.

At 10 o'clock society adjourned.

S. M. Wickersham,
Secretary.

June 17th, 1890.

Society met at their rooms at 8.15 p.m.

W. L. Scaife, President, P. Barnes, Vice-President, R. N. Clark, Director, and 27 members and visitors present.

The Minutes of last meeting were read and approved.

The President presented the recommendation of the Board of Directors that the Committee on rooms be authorized to sublet the rooms now occupied by us, and then to accept the rooms set aside for us by the Society of Arts and Sciences, in the Thaw Mansion.

He also announced that copies of Proceedings in 1889, bound in muslin, can be had on application to the Secretary, by all members whose dues are paid, on the payment of twenty-five cents.

On motion duly made and carried, the Committee on Rooms was authorized to act as the Board recommends.

The following resolutions were offered by Arthur Kirk and, after full discussion, adopted :

HERR'S ISLAND DAM.

Whereas, The United States Government is about to construct, in the Allegheny river, near Herr's Island, in the heart of the cities of Pittsburg and Allegheny, a fixed dam and lock, and

Whereas, A fixed dam at this place will, during ordinary floods which now pass by without damage to any interests, raise the surface of the water several feet, and

Whereas, Above the locality where the dam is to be located there are a number of extensive manufacturing establishments whose grounds and furnaces will be overflowed in case the dam is constructed as now designed, and this several times each year, resulting in great loss of material and the stoppage of works which employ several thousand operatives, and

Whereas, A fixed dam at this place will be liable, by reason of the narrowness of the river and the obstruction of the dam itself, to interfere with the free passage of ice in the annual break-ups of the Allegheny river, in which event, destructive ice gorges attended with immeasurable damage and probable loss of life will result. Therefore,

Be it Resolved, By the Society of Engineers of Western Pennsylvania, while fully recognizing the value of the proposed improvement which promises to extend the limits of the permanently navigable harbor of Pittsburg, that Col. Wm. E. Merrill, of the

U. S. Engineers in charge of said harbor improvement, is respectfully requested to urge upon the government the necessity and importance of adopting for this place some form of movable dam which shall prove no obstruction to the free discharge of the river during its flood periods.

On motion, the Committee on Roads was requested to report in full at the next meeting.

Phineas Barnes addressed the Society, illustrating his remarks on the Blackboard, on "Sundry Rolling Mill Appliances."

R. N. CLARK,
Secretary pro tem.

SEPTEMBER 16TH, 1890.

SOCIETY met at their rooms, Penn Building, at 8.15 P.M.

Present: W. L. Scaife, President; A. E. Hunt, Vice-President; R. N. Clark, and M. J. Becker, Directors; Past President J. A. Brashear, and 45 other members.

A. E. Hunt was elected Secretary pro tem.

On recommendation of the Board, Camille Mercàder, Jas. B. Scott, Alfred R. Davies, and James Ludwig were elected members of the Society.

Report of progress by Committee on Roads was given by T. P. Roberts.

Committee on Rooms reported through William Thaw, Jr., and J. A. Brashear, that we will probably move inside of two weeks, also report of Charles Davis, on same subject to same effect.

Letters from U. S. Department Agriculture and International Electrical Exhibition at Frankfort-on-the-Main, read; also one from Western Society Engineers, Chicago, regarding International Engineers' Congress in 1893. A committee of three to be appointed by the chair to represent this Society.

A paper was then read by E. P. Allen, on Pittsburg and its

resources, which was discussed by Alexander Dempster, T. P. Roberts, M. J. Becker, and J. A. Brashear.

After a vote of thanks to E. P. Allen, the Society adjourned at 9.30 P. M.

A. E. HUNT,
Secretary pro tem.

OCTOBER 21ST, 1890.

SOCIETY met in their new quarters in the Thaw Building.

In the absence of the President, T. P. Roberts was called to the chair, and J. A. Brashear acted as Secretary.

Forty members present.

The following named gentlemen were proposed by the Board for membership and duly elected: M. J. McFarland, Pittsburg; James Foster, Pittsburg; Edward F. Dravo, Pittsburg; George H. Hutchinson, Pittsburg; Charles F. Wieland, Allegheny. A letter was read from President Scaife, referring to the gifts to the Society by Mr. Robert Mannesmann, Alexander Thielen and Dr. Herman Wedding. On motion of Mr. B. F. Jenning, it was resolved to present a resolution of thanks to the above-named gentlemen for their very generous and fully appreciated gifts. Prof. John Langley therefore offered the following:

Resolved, That the Engineers' Society of Western Pennsylvania, hereby tender to Mr. Robert Mannesmann their hearty thanks for the generous gift he has made them in presenting to this Society his very interesting and unique specimens of tubes and other articles made by the Mannesmann process of rolling.

The same resolution of thanks was offered to Mr. Alexander Thielen, for his large collection of tools and other objects, made by the Darby process of recarbonization.

The same resolution of thanks to Dr. Wedding, for the beautiful and valuable drawings presented to the Society. On motion the Secretary was instructed to forward the above resolutions, stamped with the seal of the Society, to the secretary of the American Society of Mining Engineers, who has promised to forward them if sent by October 25th.

On motion of Mr. Reed the Committee on Library was asked to take into consideration the loaning of books to the members who may wish to take them to their homes.

The report of A. E. Hunt, our delegate to the Chicago Engineers' Society, to arrrange for the international meeting during the World's Fair in 1893, was received and read and placed on file. The report is as follows:

CHICAGO, OCTOBER 14TH, 1890.

W. L. SCAIFE,

President Engineers' Society, Western Pennsylvania, Pittsburg, Pa.

Dear Sir: I herewith respectfully have the honor to report to you that I attended the meeting held at the Western Engineers' Society Rooms, Chicago, at 10 A.M. October 14th, as a delegate of the Engineers' Society of Western Pennsylvania, as well as a delegate from the American Society of Civil Engineers, and from the American Institute of Mining Engineers. There were thirteen societies represented, including all of the national societies in the meeting. Mr. E. L. Corthell called the meeting to order, and after explaining the object of the meeting Mr. Octave Chanute was elected Permanent Chairman, and Mr. John W. Weston as Secretary. It was resolved that a committee of seven, of which the chairman of the committee should be one, should be appointed by the chair to propose a plan of action regarding a headquarters for the various engineering societies at the World's Columbian Fair, to be held in Chicago, in 1893; also at the time of the World's Fair, to hold an International Congress of engineering societies, at which papers of interest to engineering should be read. The committee of seven consisted of Mr. Octave Chanute, Mr. E. L. Corthell, Mr. William P. Shinn, with Mr. Strobel as alternate, Professor Johnson, Mr. Don Whittemore, Mr. Jesse Smith, and W. W. Curtis. A plan of action proposed by Mr. Corthell was discussed at the meeting, and was as follows:

1. To have a Joint Engineering Headquarters in Chicago during the six months of the Exposition. The question of whether the headquarters should be in the Exposition grounds or more centrally in the city was left for further consideration.

2. A staff for the joint societies of a permanent Secretary with

two assistants, at least one of which should speak the various European languages, should be appointed.

3. A rendezvous should be proposed at this headquarters for the various engineers of the United States in visiting the World's Fair, and also of any foreign engineers who should come here.

4. The duties of these staff officers should be to give information with reference to various engineering matters in the Exposition, to give information with regard to matters in the country to foreign engineers, to give letters of introduction to the various persons who are in charge of important engineering enterprises, to keep a record of the business of the joint meetings, and also of the engineer visitors to the headquarters, and to provide them with invitations to meetings. It is estimated that the cost of this staff and the headquarters would be defrayed by a subscription of one dollar per member from each of the engineering societies. To this fund also would be added a larger fund from the various manufacturing and other industries allied to the engineering profession.

5. To hold a Joint International Engineers' Congress to occupy days, presumably something like a week's time. This congress to use the English language at its sessions. That there should be one joint session at the opening, and one at the end of the sessions. The remainder of the time of the meeting the various delegates should divide into chapters upon their various subjects to be discussed. The subjects so far proposed were as follows:

Railroad Engineering, Hydraulic Engineering, Bridge Engineering, Steam Engineering, Marine Engineering, Military Engineering, Mining Engineering, Mechanical Engineering, Surveying, Electrical Engineering, Sanitary Engineering, Municipal Engineering, Materials of Construction, Geology and Metallurgical Engineering.

6. All papers for these sessions to be submitted beforehand to an examining committee to report upon the advisability of having them go before the session, and the papers to be distributed at the session or before to the delegates and then read only by title, so as to allow the entire time of the sessions for discussions of the paper. These papers to be upon novel inventions in actual use, descriptions of new tools in actual use, descriptions of new machines in

actual use. It is proposed to have the joint committee also choose a list of subjects for discussion. This data as elaborated at the meeting was placed in the hands of the Executive Committee of seven, with authority to report at an adjourned meeting upon Wednesday, October 15th. As Mr. Shinn and myself, the two Pittsburg delegates, were obliged to leave with the Iron and Steel Institute excursion on Tuesday night, we were unable to be present at the second session. We, however, represented our societies in the first session of organization, and saw that the societies we represented were formally added to the list of societies taking hold of the matter, and also for an arrangement that the secretary of the committee should send a printed letter with the official action of the society to the secretaries of each of the societies represented.

Yours respectfully,

ALFRED E. HUNT,

Delegate from Engineers' Society of Western Pennsylvania, and Vice-President.

Prof. Langley then read his paper, viz.:

EUROPEAN BESSEMER PRACTICE IN SMALL CONVERTERS.

It is well known that one of the features which distinguishes the Bessemer process from all other methods of making steel is its compactness and large output from a plant covering only a comparatively small area. It is pre-eminently a rapid operation, and this element of high speed characterizes it generally, and in this country almost universally, in all its details. Rapid blowing; prompt recharging of the converter as soon as a heat has been found; ingots swung out of the casting pit the instant danger of "bleeding" is over; usually a double set of cupolas and vessels, in order that blowing and output may not cease a single hour while repairs are going on; the mill on day and night turn. Everywhere speed made the primary consideration, so that one might almost regard the converter as a mere pocket or enlarge-

ment in a pipe through which a stream of melted iron is passing from the cupolas to the molds, this stream not being strictly continuous only from the necessity of arresting it periodically for a few minutes to inject air into it. These are the conditions under which the Bessemer process is usually operated, and which are considered to be those on which pecuniary success depends.

But there are cases when these elements of high speed and large output may be actual drawbacks, because other objects or conditions interfere with them. For instance, in the case of an iron foundry to which a steel casting plant is to be added, where a large number of small objects is to be made, such as wheels for trucks, or parts of agricultural machines, the diversity of articles and the large number of molds requires that the steel shall not be brought to them in fluid masses of five or ten tons, but gradually in quantities of a few hundred pounds only. Or, as a second illustration, suppose a blast-furnace at a distance from others or from a large industrial centre, and let the owners of the furnace desire to make Bessemer steel ; unless their stack is a very large one it could not supply the fifteen to twenty tons an hour, which a converter of the usual size would consume.

Thus it may be conceded that abstractly speaking small converters are desirable, and that there would be a large field for their use if they could satisfy only a moderate requirement in the way of economical production. That they can do so under special circumstances facts have already shown, for the two supposed cases just cited have their counterparts in European practice to-day, and are typical of the two classes of cases, namely, steel foundries and small blast-furnaces.

The conditions of pecuniary success then, are first, for foundries the manufacture of a large number of small or special shapes, to be cast in dry sand molds, where a higher price per pound will cover the increased cost of Bessemer steel that has been made in small quantities at each blow ; and second, for isolated blast-furnaces making a high grade of pig when the superior quality of the steel produced will enable it to compete with the cheaper rail and structural steel of large plants.

During the summer of 1888, the writer visited a number of

European establishments using small converters, and the following is a brief account of their distinctive features :

In France Monsieur Robert had just brought out a special side blow converter, for which he claimed several original features; also it was alleged that very surprising technical and commercial results could be obtained by it. The process had just been installed in a foundry near Montmartre, in Paris, under the direction of Mons. Robert himself. At the time of my visit the plant consisted of a single converter, a cupola, and a casting floor of about 2500 square feet. The construction of the converter and the management of the blow were so similar to the practice which I afterwards saw in Belgium, that its description may be deferred for the moment. A sample of metal taken directly from the vessel was forged under a small power hammer to a bar one inch by one-half inch. It was very red short, and would not stand bending hot to more than fifty degrees from the axis of the bar without cracking. When broken cold its fracture was dirty and granular, and apparently indicated a metal about half way between cast and wrought iron.

It is only fair to Mons. Robert, however, to say that the plant had just been installed, was confessedly working imperfectly, and that information since received from parties who have purchased the right to use this method, contains the report that a fair quality of soft steel can be made by it.

In Belgium the small side blow converter was in successful operation at the works of Mons. Cambier, at Marcinelle, near Charleroi. This gentleman gave me every opportunity for investigation, even to showing his records of charges and yields, and a full set of drawings. He claimed to be working under the Belgian patents of Walrand, and thought Robert's process to be identical with Walrand's.

It would be out of place here to enter into any discussion of the priority of these two inventors. What was obvious, however, was that the Belgian operator had been using the method for over two years, and was about to double the capacity of his plant by putting in a second vessel.

The Walrand converter has a capacity of about a ton, and has

externally the shape of a cylinder terminated by a truncated cone; its cross section is D-shaped. On one side a short distance above the bottom there is a rectangular wind-box provided with six glass covered peep holes.

Inside, the vessel is lined continuously on the sides and bottom, for the latter is not made removable. Opposite the wind box and about twelve inches above the bottom lining are a number of rectangular openings or tuyeres for the admission of the blast. These tuyeres do not pass through the lining either radially or tangentially, but are pointed midway between the two directions, making an angle of about thirty degrees with a radius in a horizontal plane and an angle of thirty to forty with the same radius in a vertical plane. The effect of this is said to be that the blast penetrates deeply into the metal, and at the same time gives the latter a rotary motion around the vertical axis of the vessel, thus bringing all portions of the melted pig successively in front of the tuyeres.

The converter was mounted in a low frame, which barely permitted it to swing clear of the floor. Two geared wheels connected the trunnion of the vessel with a large iron windlass wheel on the side of the fixed frame, so that four men were able to turn the converter down or up. The management of a *blow* was as follows: The vessel was turned on its side and about one ton of metal was poured in from a ladle. It was then put in an inclined position and the blast turned on, then it was very gradually brought up to the vertical and blown for twelve minutes. It was now turned down nearly horizontally and the slag run off. Then a man standing in front threw in by hand lumps of cold ferro-manganese, which he tried to distribute evenly over the surface; then there was an interval of about five minutes in which everybody took a rest, some of the men lighting their pipes. This leisurely proceeding was in marked contrast to the activity which follows the termination of the blow in American practice.

On looking into the open mouth of the converter I could see several lumps of ferro which had lodged in the slag on the sides and would not melt, so that this would appear to be an injudicious method for putting a definite amount of manganese into the metal.

At the end of five minutes signs of life became apparent. Small ladles holding about two hundred pounds were brought up to the mouth of the converter, and were filled successively by the men at the windlass who tipped the converter carefully. These ladles were each taken by two men to the sand molds on the floor, the entire operation of filling the ladles and pouring the molds being precisely like the usual practice of an iron foundry.

In several instances the ladles filled with steel were allowed to stand several minutes on the floor before pouring, because the metal was too hot.

This entire freedom from the evils of premature chilling was a great surprise, and I think would be so to any one familiar with the customary behavior of Bessemer steel. The explanation appears to be two-fold; first, from the composition of the metal which was, at the time of my visit, about 0.40 of carbon; thus the melting point is materially lower than for soft steel of the customary composition; second, the side blow converter certainly maintains a very high temperature, doubtless owing to a portion of the blast always playing over the surface of the bath. Heavy brown clouds of burnt iron appeared almost at the beginning of the blow, and grew increasingly prominent to the end.

As to the economy of the operation the losses in the converter by oxidation are said to be fully twenty-five per cent. The metal made at Marcinelle was fairly soft and tough. I inspected some fifty wheels after they had been bored and faced and saw only a small proportion of blow holes. Mons. Cambier says he has no difficulty in making any carbon between 0.20 and 1.00 per cent. He was so well pleased with his two years' trial of the Walrand process that he was then building a second converter.

The second head, small converters near detached blast-furnaces, finds its principal illustration in Sweden. There the conditions are quite peculiar, namely, remarkably pure ores, very cheap labor, and only charcoal for a fuel. The only salvation for a Swedish iron-master is to make high quality the first consideration; everyone knows how well they have succeeded in their pig-and bar-iron, and they have done equally well in their steel practice, for it is quite generally conceded by European makers that the Swedes

have brought their Bessemer steel up to the very highest quality this type of metal is capable of attaining.

Owing to the complete lack of native mineral fuel, and to the large number of rivers, the iron establishments are always located at some source of water-power, and so numerous are these little forges and furnaces that, wherever the scenery is particularly wild and pleasing, there one is sure to find the manufacture of iron going on in some picturesque collection of wooden buildings which detract little or nothing from the landscape, because there are no mountains of slag and ashes to cumber the ground and no smoke to poison the air.

Of the many establishments in Sweden I will select two, one as makers of low steel and the other of high.

At Avesta, on the river Dal, at the site of a splendid water-power, are located a charcoal blast-furnace and a very curious small Bessemer plant; perhaps it is the very smallest in the world. The steel made here is nearly dead soft, and is used principally for galvanized sheets of exceptional quality. The converter is only a few feet from the base of the blast-furnace, and so placed that the metal can be run directly into it without requiring a ladle. The shape of this converter is very peculiar; externally it resembles a barrel about six feet high by four in diameter; there is only one opening in it which is placed on the side just below the top, and is only six inches in diameter. The bottom is removable in the usual way. By this plan the flame issues at right angles to the vessel when the latter is vertical. To charge it the converter is turned till it is nearly standing on its head; rather less than one ton of pig is run in directly from the blast-furnace, and the converter is turned up and blown. The pressure of the blast is eighteen pounds.

By having such a very small throat the flame issues in the form of a blow-pipe and with a deafening roar. The progress of the decarbonization is very sharply indicated by the changes in form of the flame which gradually shortens till it just hovers around the mouth of the vessel. This indicates about 0.10 per cent. of carbon, and is the point aimed at. A few lumps of ferro-manganese are thrown in by hand and stirred with an iron bar. At

the end of three minutes a slight reaction is apparent. The vessel is now turned over and poured, slag and all, into two ten-inch molds, and the latter are purposely slightly overflowed in order to carry off the slag.

In the above practice it will be noticed that no recarbonizer is used. The metal is blown *down* to the required carbon and then the process is arrested. This is universally the case in Sweden, and is in marked contrast to the customary American and English practice, the Swedes always aiming to stop at the required carbon, but never to overpass it. The theory of the very small throat is that by causing a back pressure in the upper part of the vessel the temperature of combustion of the metalloids is raised, and thus a higher heat is obtained; also that less metal is mechanically projected by the blast. However this may be, it seems to be pretty well established that the long, sensitive, flame, with its inner cone and outer mantle, is an aid in judging of the progress of the decarbonization.

At Sandvigan, a very high grade of steel is made, both in the open hearth and by the Bessemer process. Nearly all of the metal produced in the latter is high carbon steel, which is used largely for tools. Probably no material of its type stands higher; it is said to nearly approach crucible steel in quality. The converter has about three tons capacity. The iron is brought to it in a ladle through an underground tunnel from a blast-furnace in the vicinity. The converter is of the customary form, but has only a seven-inch opening at the throat.

If, for example, 0.80 carbon is to be made, the blowing would be stopped when the flame indicated a close approach to 0.90. A sample is then removed by a hand-ladle and cast into a test ingot which is removed as soon as it has set to a small power-hammer and forged into a bar of about one-half by three-eighths of an inch. This forging can be done in twenty-five seconds. The bar is now ready for the mechanical carbon test, which is made by heating it in a charcoal fire till it is near its melting point and then hammering it. At this temperature high steel is of a sandy texture, almost without cohesion and readily crumbles under the stroke. A bar of known composition is sometimes used as a standard, with the

trial one. The higher the carbon the lower is the temperature at which the steel crumbles. The test is made very quickly and seems to be fairly accurate, for several Swedish steel makers told me that an experienced smith could determine the carbon within from five to six points, provided that the metal was pretty uniform in its other constituents.

In the supposed case at Sandvigan, if the smith reported, say, 0.95 carbon, the converter would be turned up and blown for a few seconds longer and then either poured or sampled a second time according to the degree of uncertainty present, no ferro-manganese being used.

As an example of actual practice, here is the analysis of the pig and steel made from it, taken from the books in the office at Sandvigan :

	Pig.	Steel.
Silicon,	1.10	.066
Manganese,	3.08	.437
Graphite,	3.68	——
Combined carbon,	.78	1.20
Phosphorus,	.015	.022
Sulphur,	.014	.01

In regard to the apparent removal of sulphur it should be noted that the analysis is of an average of the pig, while that of the steel is on an individual blow.

The low silicon and high manganese is quite general in Swedish practice, for it is forced upon them by circumstances. The low temperature of their small charcoal blast-furnaces produces low silicon pig, and consequently a deficiency of heat in the converter; to make up for this, iron-ores carrying this element are used, or even manganese-ore may be charged into the blast-furnaces. As a necessary consequence, by having enough of this element in the pig a proper quantity can be left in the steel at the end of the blow without the necessity of using ferro-manganese or spiegel.

The differences between the Swedish and the customary methods of Bessemer practice are that by the former there is less loss of iron by oxidation, and it is claimed a more homogeneous metal is pro-

duced; but also it is conceded that the difficulties of hitting the carbon desired are considerable, while by the method of recarbonizing these difficulties are greatly lessened, and a much greater speed of working can be attained.

Obviously, the conditions of commercial success for small converters are quite special, and are limited to those similar to the Swedish, where exceptionally pure ores and low-priced labor permits slow working, and quality, rather than quantity, to be the chief aim of the steel maker.

In the course of his paper Mr. Langley made the following observations:

This paper is not so much directed to theory, or to giving a large number of statistics, nor is it addressed to those members particularly who are versed in the details of American Bessemer practice. It is rather a descriptive or narrative paper than one of a strictly professional character. It occurred to me that it would be interesting to give an account of some of the peculiarities of the European practice in small converters, because, while there are no very small converters in operation in this country, yet in certain respects the European practice leads that of all the rest of the world. I mean the Swedish practice in the matter of quality.

In explanation of a drawing of the Walrand converter he said:

The metal is also in rotation around a vertical axis. The force of the blast is intended to keep the metal in an inclined position, but even if the drawing is somewhat exaggerated it is evident that there is an enormous area of contact between the incoming blast and the iron. It is quite unlike the ordinary converters where the blast bubbles up through the metal, because in the ordinary converter the blast in passing through the metal meets its carbon and its silicon in excess, but here the blast being blown on the top of the metal the superficial stratum of carbon and silicon is oxidized almost immediately, and the action is expended upon the iron.

In speaking of Swedish practice he said:

Now, by the method I have described, two results are obtained. One is that the flame instead of issuing in a large blaze has almost precisely the character of a blow-pipe flame. It has a dark mantle like that of a Bunsen burner. At the commencement of the blow

the flame is of course very short, but as soon as the carbon reaction sets in there is a cone seen hovering about the mouth of the vessel. It grows longer until it has proportionately the outlines of the sketch. Now as the carbon begins to burn out we have in our ordinary practice no means of telling the rate at which the carbon is burnt out. We can look in our spectroscopes and we can get every tint of the flame, but when the carbon goes out it goes like a flash. The Swedes desire to know the rate at which the carbon is leaving the metal because they do not blow all the carbon out. They blow down to the carbon they want to get and then stop. By this arrangement the rate at which the carbon is going out can be told by the form of the flame.

At the time of my visit of course I was quite inexperienced in that particular flame, but even inexperienced as I was there was no difficulty in seeing that there was a very close connection between the burning out of the carbon and the appearance of the flame. After the maximum is passed and the carbon begins to disappear, of course this flame begins to shorten, and shortens with great regularity until the carbon is reduced to ten points. The inner flame is just hovering over the mouth of the vessel and the dark mantle has almost entirely disappeared, leaving only a little flickering flame. They say by the shortening of the flame they can tell the disappearance of the carbon far better than by the customary English and American practice of watching each tint of the flame.

Another result which they find of great service to them, and this I must take entirely upon their report, for I have no means of confirming it, is that they have a very high temperature in these small vessels. There is a less total generation of heat than in our large vessels, and the ratio between the volume and the surface is, of course, very different from that of a 5-ton converter. Therefore the Swedes are continually fighting against the danger of chilling. They say by having the aperture of the throat reduced down to about six inches they get a much higher temperature, and apparently they do. The theoretical explanation of that may be found in the fact that the higher the pressure the greater the temperature of combustion, and, therefore, the Swedes have the theory, and claim to have the practice as well. The result of this throt-

tling is to produce a terrific sound, the most deafening I ever heard.

I had every opportunity to witness the mode of making carbon tests. The test-bar is taken to the forge and placed in the fire side by side with a second bar of precisely the same shape and cross-section in which the carbon has been determined by the chemist. Then the two are brought up to a welding heat. Now, high carbon steel at a welding heat becomes sandy and mushy. The two bars are taken by the smith, laid across the anvil and struck a heavy blow with the hammer. The steel is in both cases mushy, and flies off like so much semi-melted sand. At the second blow it does not fly so rapidly, at the third it is more ductile, and at the fourth or fifth it becomes very ductile. The number of blows necessary to strike before it ceases to fly around the shop is a very good indicator of the amount of carbon the steel contains. Certainly according to their statements they can determine the carbon very closely. That the carbon can be determined very closely by this means I was able to prove by experiments made in this country. With a little care and skill a man can hit the carbon within 15 points on high carbon steel, and I have no doubt that a man who would give much time to it could determine within five to ten points.

At Sandvigan, they allowed me access to some of their books at the office. They seemed to have no unwillingness at all to tell everything they were doing, They allowed me to copy from their books as many analyses as I cared to. I will only give you one, and I quote this with this confidence that it is not a selected example. I went to their large office ledger and was allowed to turn over page after page at random and copy analyses. Therefore, this shows regular work at Sandvigan, and is the analysis given in the body of the paper.

One is struck with the peculiar composition of the pig. The silicon is remarkably low. In this country we could not blow pig containing as little silicon as that. You will notice the manganese is quite high. This explains the peculiarity of their practice. The reason why they do not have to use any ferro is also apparent. This very high steel was stopped say at 1.20 carbon. By

that time the original 3 per cent. of manganese had burned down to .43, which is a very fair quantity. If they had been blowing lower than that the manganese would have been somewhat lower, but in no case in their practice do they permit the manganese in their pig to get so low as to blow out before the carbon burns out.

They attribute the high quality of their metal, which is unapproachable by Bessemer metal made anywhere else, to this. They say in our practice the quantity of oxygen introduced is so great that the manganese never perfectly takes it out again, and, therefore, the metal is never perfectly homogeneous. By their system it must be homogeneous.

Certainly, whether their theory is correct or not, we know their metal stands very high indeed. It is obvious, at the same time, that this practice, with a specially obtained pig, and blowing down very leisurely, is one that could only be commercially successful under some such conditions as exist there, namely, very pure ores and pig, and a steel which brings a fancy price in the market.

Discussion.

A Member: I would like to ask Mr. Langley how they handle the iron coming from the blast-furnaces. He speaks of the very small quantity they charge into the converters at one time, and the very leisurely manner in which they handle it after coming to the converter. And I would also be interested in learning how they handle the steel when it was poured from the converter.

Prof. Langley: The converters are near the blast-furnaces, which are very small. The metal is usually run in the ordinary way. The ladles are much like ours.

The other part of your question reminds me of a point. At some places they employ what is called a converter-ladle, but quite a different thing from the French converter-ladle of which I first spoke. It is not usual in these small vessels to attempt to use a ladle at all. The molds are brought right up to the mouth of the converter if possible. But at one or two places I saw the following device used, which permits the steel to be poured without introducing the slag into the mold. This special device I first saw at Nykroppa, where they make a specialty of 1.50 carbon steel,

running that out into 14-inch ingots. The converter here contains, if full, about three tons, but they do not charge much more than a ton and a half. It is the usual pear-shape form of a vessel, but the neck is very short and very wide indeed. Apparently this was 18 inches in diameter. Now that appears quite opposed to Swedish practice, but we find this lined up so that the opening is only 7 inches. Great pains are taken to make the bricks very true, lying accurately within the plane of the converter mouth. The ladle is detached wholly from the converter during the blow, is warmed by a small charcoal fire; then, at the end of the blow, the converter ladle is brought up against the mouth of the vessel. There are lugs which I have not shown in the sketch, the joint is covered with fire-clay and then by a hydraulic arrangement it was forced up against the mouth, and the ladle and the converter are practically one vessel. In tipping down, the steel will run into the ladle but the slag is left behind in the vessel. The ladle being a part of the converter cannot be carried about, and the molds must be brought to the ladle. They are mounted in an apparatus like a large umbrella-stand rotating around a central pivot. When I was there, they had six 7-inch molds in this umbrella-stand, which was sunk into a pit below, and by rotating, the molds are brought under the ladle and filled in the usual way.

A MEMBER: What was the interval between the charges?

MR. LANGLEY: From fifteen minutes to half an hour.

MR. BRASHEAR: I would like to ask Prof. Langley if he saw many of the castings from these small side-blow converters that were turned and worked afterwards. Did you notice particularly that they were more free from blow-holes than the castings we are having now from Bessemer? The best castings I have seen in this country are from Chester. I am thinking now of having some very fine castings for some large objectives, in which the co-efficients of expansion and contraction are practically the same, and we find very great difficulty in getting such things free from blow-holes.

MR. LANGLEY: I prefer not to say anything at all about American castings, but I compared these castings made at Marcinelle,

with a great many other castings which I afterwards saw in the great machine shops in Saxony, where they are using steel from all parts of Germany, and certainly the blow-holes in the Saxon steel were very much larger and more numerous than in the small works at Marcinelle. Whether that would be so everywhere I cannot say.

A MEMBER: It appears to me that the first process mentioned by Prof. Langley is very much like our Clapp-Griffith. The facts I take it are much the same. We get a high heat with apparently low silicon. In our ordinary Bessemer practice we take advantage of this fact that iron is oxidized by a very small amount of blast through the tuyeres and in turn brings up the heat. We do not like to do it for there is an enormous waste of iron; but in some cases it is necessary.

These high heats I may say that in ordinary steel for rolling, it makes a very poor steel. It does not roll well and is usually hard and brittle, but for this particular purpose it would be necessary, of course, in pouring it for small castings.

There is one advantage that we see that the silicon is brought down, whereas in ordinary practice in getting a heat that is high, the silicon would also be high. But in the rolling of steel the enormous waste that would be entailed by that method of blowing in the ordinary converter makes us avoid that method. Speaking of the low silicon of the Swedish practice we find that it would be impossible in using cupolas to blow metal with so low silicon, but where we take the metal directly from the blast-furnace where the initial heat is high we find we can blow with silicon even lower than 1.10.

Referring again to the converters where the steel is made for castings, I should think from looking at that analysis that it would be much cheaper to make it in the open hearth rather than having the great oxidation of the Bessemer converter, and be able to control it much better.

MR. ROBERTS: I should think from your description of that one converter where the blast is directly on the surface that from the revolving movement it would bring all the metal in contact with the blast very rapidly.

Mr. Langley: The shape of the metal in the vessel I know nothing of from personal observation.

A Member: You spoke of hammering 14-inch ingots of 1.50 carbon. For what purpose was that carbon used, do you know?

Mr. Langley: I think they hammered them down into 14-inch billets and sold them to the Sheffield steel makers.

After which Society adjourned.

J. A. Brashear,
Secretary pro tem.

November 18th, 1890.

Society met at their rooms.

Meeting was called to order shortly after 8 p. m. President Scaife in the Chair, Vice-President P. Barnes, Director Wilkins and twenty-seven members present.

On motion T. P. Roberts was made Acting Secretary, whereupon the minutes of the October meeting were read and approved.

The President read a letter from S. B. Fisher, resigning his membership in the Society owing to his permanent absence in the west.

The following applicants having been favorably reported upon by the Board were duly elected members of the Engineers' Society of Western Pennsylvania:

Harold E. Stowe, Benjamin Page, J. Everett Lobingier, Alfred Randolph, Peter Doxrud.

Charles Davis reported that the Library Committee not having met during the month, no action had been taken in regard to members being permitted to take books from the library. T. P. Roberts reported that there had been no meeting of the County Road Committee, though the Committee expected to report later on matter for the action of the Society.

President Scaife read at length an interesting report of the convention held in Chicago, October 14th and 15th inst., to consider the establishment of an engineering headquarters, and the

holding of an International Congress of Engineers during the World's Columbian Exposition, 1893. Captain Alfred E. Hunt, delegate from this Society, not being present, the debate upon the report was, on motion, postponed until next meeting of the Society.

Charles Hyde then read the following paper, illustrating his remarks with diagrams on the board, and with blue prints.

HYDRAULIC MILL APPLIANCES.

The underlying principle of hydraulics discovered by Archimedes, viz., that pressure applied to a fluid acts equally in every direction, is one that has been of very great importance, and of very general application of recent years in the arts, and has nowhere been more generally used, nor with more advantageous results, than in the manufacture of steel.

I propose briefly to call the attention of the association to one or two recent developments of hydraulic appliances, which may probably be of interest to most of our members, and which I trust will lead to discussion of benefit to every one.

I may state here that these appliances have been introduced by engineers well known in this district, and some of which appliances are at present in operation in Pittsburg and vicinity. I take these as being more familiar to myself, and as likely to be of more interest to this association.

Turning first to the casting department connected with either the Bessemer or O. H. process, as coming first in the line of conversion of the raw material of the mill, into a finished product and passing over the hydraulic cranes, hoists and turning arrangements as being familiar to every one, I should like to call your attention to an ingenious arrangement for quickly and easily stripping off the moulds from ingots, combining as it does, the lifting of the ordinary crane with the thrust of the ingot extractor in one operation, so that in no ordinary case of sticking need the ingot and mould be lifted out of the pit, or off the car together.

The general outline of the machine is illustrated in Figs. 3 and 4, page 142, and the whole operation is controlled through a

system of levers by one man who is well away from the heat of the ingots.

Preferably the ingots are cast on cars, two on each car, and run underneath the track on which trolley carrying the extractor travels.

Three pipes connected with different parts of the machine by means of swivel joints, give the various movements required to obtain the desired result, one pipe leading to the cylinder above the piston 6, a similar pipe leading to the cylinder below the piston 8, and the third pipe connecting with the space between the pistons by means of a pipe fixed to and passing through piston 6, and which pipe slides up and down inside the tube 21, thereby keeping the connection open, no matter in what position the piston may be.

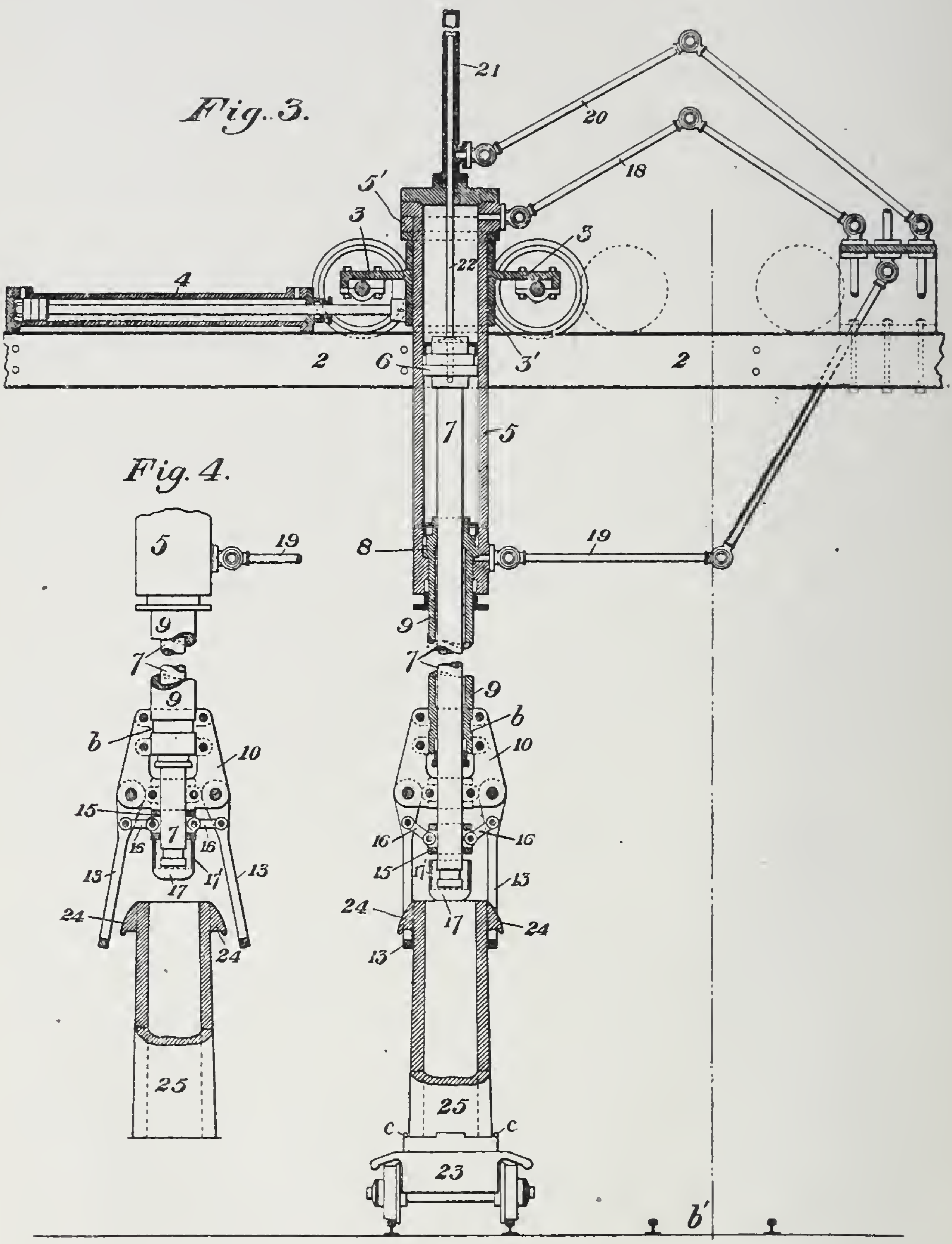
Assume now that a cast has been made and the buggies run within the range of the machine. The trolley is moved if necessary, until the ram of the extractor is directly over the ingot to be stripped, the rams 7 and 9, having been previously raised to a sufficient height by admitting water through pipes 19 and 22. The centre ram is raised independently of the outer one (through which it slides) by the admission of water underneath piston 6, and by the act of rising, opens, by means of the toggle joints, the links suspended from the outer ram, until the collar carrying said toggle joints strikes against the under side of ram No. 9. When the areas of the pistons above and below being equal the two rams remain balanced, and form, owing to the water between them, practically one ram.

Water admitted now below the piston No. 8, would raise the two rams together, carrying up the links open as shown in Figure 4. This would represent the position when the buggy carrying the ingot was run underneath.

By exhausting the water from pipe 19, the rams now descend until the links still being open, are opposite the lugs on the mould, then by exhausting the water from the space between the pistons, the inner ram falls by gravity, and in doing so allows the collar to fall, which draws in the links against the side of the mould, so as to fit under the lugs in the manner shown.

The connection of the links by toggle levers with the collar serves to equalize the motion of the links, and to cause them to

H. AIKEN.
MILL APPLIANCE.



close symmetrically upon the mould, the operation of engaging the links being entirely automatic.

The valve in pipes 18 being now closed so as to confine a body of water above the piston 6, to prevent it rising, and the valve in pipe 20 being open to exhaust, the valve admitting water below piston 8 is opened causing the outer ram to rise, carrying with it the yoke and links, and as the links are connected with the mould, and the ingot is prevented by the centre ram from rising, the mould is stripped from the ingot, leaving it standing upon the car whilst the mould can be swung round and deposited automatically upon the ground, or upon another car.

Should the pressure upon piston 8 prove insufficient to effect the stripping, owing to the ingot sticking, water may be admitted through pipe 18, into the top of the cylinder, when the whole sectional area of the cylinder comes into effect and the cylinder itself rises slowly in its socket in the trolley, carrying with it the piston 8, and the ram, links and mould attached. As soon as the initial frictional resistance is overcome, the water may be shut off the top, when piston 8 will continue to rise and coming in contact with the upper piston will raise the inner ram from the ingot.

To deposit the mould, the pipe below piston 8 is opened to the exhaust, and the mould lowered by gravity upon the ground or a car, as the case may be, and the disengagement of the links is effected by admitting water through the upper pipe into the space between the pistons when the inner ram rises, and its shoe coming in contact with the collar causes this to rise and push out the links into the first position, when the machine is ready to take hold of the next ingot.

The apparatus thus affords an efficient means of extracting ingots without any subsequent handling of the ingots or moulds, and can be operated much more rapidly than it can be described, and when it is stated that two ingots may be extracted simultaneously it is at once apparent that the device is as effective as a time and labor-saving appliance as it is ingenious in its construction and design.

The apparatus may be carried on the jib of an ordinary crane, or suspended in any way most convenient or desirable to suit the particular condition of any given case, as it is entirely self-contained and free to move in any direction, the connection being maintained by means of suitable flexible or jointed pipes.

Feed Tables for Rolling Mill.

Had time allowed it was my intention to have discussed one of the most successful hydraulic methods of charging and drawing ingots from the re-heating furnace, in connection more particularly with plate-mill work, but, if agreeable to this Society, that, with several other interesting appliances, can be treated at some future meeting more fully than was possible to me on this occasion.

Assuming, however, that our charging and drawing has been properly taken care of, a novel arrangement in mill tables, lately introduced by Mr. Aiken, will probably prove of interest and repay a short investigation.

The system may be applied to the rolling of plates, rails, structural material, etc., but I propose to consider it more in detail as applied to the rolling of plates where two stands of rolls are used, one for breaking down and one for finishing.

The system consists briefly of the ordinary feed tables, composed of rollers carried in side pieces, and driven by bevel gearing, the whole table, and this is where the novelty and the special advantage of the system comes in, being carried bodily on the jib of a crane, hydraulic preferably, and capable of being raised and lowered to suit the forward and back passes of the mill, and also capable of being swung round to the next pair of rolls, where the table can be raised and lowered as before. The platform of the crane is so arranged on the jib as to carry round with the tables the engine for operating the same, the hydraulic cylinder for operating the manipulator, the necessary valves for controlling the various motions, and the one man necessary to operate the whole.

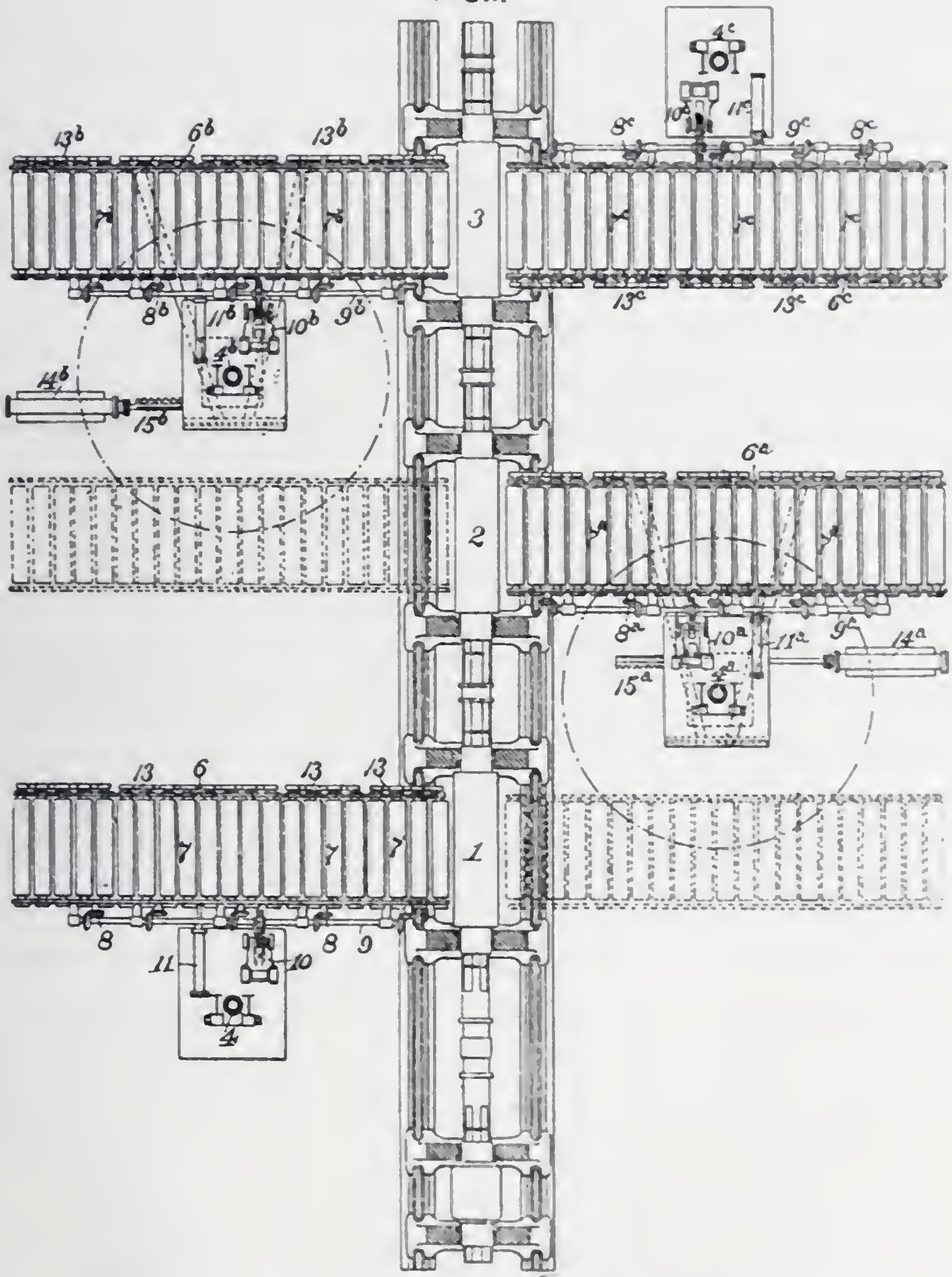
Assuming now that an ingot has been placed on the table opposite the roughing-down stand, the table is raised or lowered, as the case may be, to suit the direction of the rolls, and the rollers set in motion in the usual way, the rollers on either side being rotated in the same direction.

The pass having been made, the tables are adjusted to the proper position for the return pass, and the direction of the rollers reversed. When sufficiently broken down the ingot is swung round on the table to the finishing-stand of rolls, where the same

process is continued till the plate is finished, when the tables may be swung round into a position parallel with the roll-train, or approximately so, and transferred to a line of cooling or transfer-tables.

H. AIKEN.
FEED TABLE FOR ROLLING MILLS.

FIG. I.



In cases where three stands of rolls are used the cranes might be arranged as shown in the accompanying sketch, where tables 4 and 4*c* are adjustable vertically only, and tables 4*a* and 4*b* are adjustable vertically, and also capable of being swung round into line with stands 1 and 2 and 2 and 3 respectively.

In this case the ingot, after being roughed down on stand No. 1, is swung round to stand No. 2, and after being rolled down, or shaped still further on stand No. 2, it is transferred to No. 3, when tables 4 and 4*a* are in a position to take hold of another ingot, which can be roughed down whilst the previous one is being finished on stand No. 3, so that less time is lost by any part of the mill remaining idle.

Another arrangement of the tables may be made, where three or four stands of rolls are used, whereby the tables may be swung into line parallel with the train of rolls, forming a continuous table, by means of which the ingot may be transferred from No. 1 stand to No. 2, 3 or 4 at pleasure, and as any one of them, or all of them in turn, may be still further reduced or shaped.

Still another arrangement of the tables may be made, in which the tables are divided, the section next the rolls being pivoted near the end farthest from the rolls, and raised and lowered at the end nearest the rolls to suit the forward or back pass, whilst the outward section of the tables would be capable of vertical adjustment and also of being swung round from one stand to the other as before described, thereby acting both as transfer-tables, and also as serving to lengthen the feed-tables.

The ingot might by this arrangement be broken down on stand No. 1, and, when becoming too long for tables No. 1, be transferred to tables No. 2, where it would be finished, whilst during this finishing process a fresh ingot would be placed upon tables No. 1 and reduced ready for transfer, thus making the operation continuous.

The foundation work required for tables of this type is very small, and the floor space under and around them can always be kept clean and tidy, a point of considerable importance with an orderly and careful mill manager.

The methods of admitting water to these table cranes for operating the various cylinders is an interesting one, as some four separate streams of water must pass in and out of the centre post of the crane, whilst at the same time it must be free to revolve in any direction.

This is effected by the arrangement of pipes and glands shown

herewith, where the centre pipe is fixed and passes through the hollow centre of the crane.

This centre pipe is divided into four sections having outlets at different elevations, and over each of these outlets a sleeve is fitted, packed top and bottom, but free to revolve, and to this sleeve a pipe is attached which passes down to the nest of valves in front of the operator. By a new method of effecting the turning, however, only two pipes are required to enter the crane, one inlet and one outlet, all the other pipes being fed by or exhausting into these two pipes.

The lifting-ram of the crane is made to work into two cylinders as shown, the one cylinder being in constant communication with the pressure system, and so acting as a balance to take up just as much of the dead load as is thought desirable, the other cylinder effecting the raising and the lowering of the tables, the water passing into this cylinder practically representing all the water consumed as far as vertical adjustment is concerned.

It is also proposed to drive the rollers by means of a small hydraulic engine, so that the whole of the movements of raising and lowering, rotating, adjusting by means of manipulators, and passing to and fro through the rolls, are effected by hydraulic power.

I may add, in conclusion, that the hydraulic ingot extractor is being put in at the new plant of the Pennsylvania Steel Company at Sparrow's Point, Md., where the whole system of casting and re-heating has been arranged to suit this special method of stripping and handling, whilst the transfer tables will probably be put in for the Central Iron Company, of Harrisburg, in the early spring.

Discussion.

P. Barnes: It may seem somewhat discourteous to enter a general demurrer at this time against this class of machinery, but I venture to do so, as my experience has forced me to study the most rigorous simplicity in all such fixtures, and, indeed, I question seriously whether there can be any useful outcome of apparatus of this sort. It may not be expedient to enter into minute details, but I have an impression that the exposure to

heavy blows, certain to be encountered in the use of such a table, and the need that exact adjustment should be maintained, would be fatal to its ultimate commercial success.

W. L. Scaife: Do you refer to the table or the ingot extractor?

P. Barnes: I refer to both of them. So far as my own opinion goes, they are open to great criticism. I should not favor them at all.

Mr. Winn: How are the rollers driven?

Mr. Hyde: They are driven by a small hydraulic engine.

Mr. Winn: Are the rolls three-high?

Mr. Hyde: It is a three-high mill. Of course (turning to Mr. Barnes), the table, when swung round, presses against the stop in the housing, and is held against this stop by the full force of the rotating cylinder, and slides up and down, always in contact with the stop. The effect of the hammering is only to be determined by experience.

P. Barnes: If some further remark may be permitted, I may say that during the last four years I have had some oversight of a reversing blooming mill for rolling steel billets. Upon the basis of the experience thus acquired, a new mill has been built and put in operation at the works with which I am connected, and in the design of this mill it was made nearly the chief study to eliminate absolutely the complication of lesser details, which seem to find so important a place in the mechanism now under discussion.

W. L. Scaife: In eliminating these troublesome details have you increased or decreased the cost of the work?

P. Barnes: Decreased it by a long margin.

W. L. Scaife: In the wages question?

P. Barnes: Yes, in a very important proportion. The type of machinery I referred to is wholly different from this, in the handling and in the manipulating. And yet it may be fair to say that there is a field for mechanism of this kind, and some parts of that field have been usefully and successfully occupied, largely by the gentlemen whose names have occurred to us in this connection, to their great credit, and I have no doubt to their entire satisfaction. What I have seen of these forms has interested me

greatly, but I think in the present case the idea has been carried too far. There is a limit to refinement even in this direction, and I doubt its expediency very much.

I. WINN: I agree with Mr. Barnes in this respect. I have seen instances of this kind in rolling mills. In the hands of the ordinary roller they do not amount to anything. No doubt Mr. Aiken could operate these tables successfully, but very few rollers could do it.

W. L. SCAIFE: There are fewer men employed about these machines.

I. WINN: There may be fewer men employed at the rolls but there are more employed outside in maintaining the machinery. When you have a great deal of complicated machinery it requires a great many more men to maintain it than when the machinery is simple.

From what I have seen of this machinery I believe it would, in the hands of a competent person, be successful; some person that has judgment and mechanical ability. That is the kind of men that will be required for such mechanisms.

T. P. ROBERTS: While I can say that I was interested in the paper, I confess to not fully understanding all its details. This, however, is only natural, as the machine is novel and somewhat complicated, but such a difficulty can be overcome by reference to the diagrams, should they be printed with the paper. We have been accustomed of late to hear much concerning the possibilities of forces and mechanical movements, already devised, and yet to be generated, from electricity, but I am tempted to believe that the possibilities of hydraulic mechanism are as great, if not greater, than exist in any other field presenting itself to the genius of the engineer. The equalized pressures, reliable action, economy, and avoidance of the many ills and dangers attending the use of fire, makes hydraulics very inviting, and when we have mastered, or at least are able to control within fixed limits, the reactions of water, it will no doubt supersede steam in many instances. We may at least hope, therefore, to yet see its only needed quality, viz.: expansiveness compensated for by an expenditure of a portion of its force acting in reserve. I am glad to know that so

much careful thought has been expended in this direction on a machine specially designed for operating some of the heavy appliances connected with our great iron and steel works, and trust it may prove to be all that its skilful designer claims for it.

Mr. Hyde's paper was discussed by Phineas Barnes, Isaac Wynn, President Scaife and others.

As pointed out in conversation with members interested, Mr. Hyde wished to add that, although the description and sketches may give the impression that these appliances are complicated in construction, difficult to work, and costly to maintain, they are, in reality, much simpler in construction and operation than some other hydraulic appliances in use at Homestead and elsewhere, against which every objection raised to these tables and ingot extractors was raised, when the Homestead appliances were first introduced, but the objections were proved to be as groundless in this latter case, as they will doubtless prove to be as regards the former.

Of course men of intelligence and mechanical skill will be required to operate them, and, fortunately, such men are plentiful.

Whether the average roller possesses the necessary skill or not, is beside the question, as no roller has anything to do with the manipulation of feed tables; this is the province of a mechanic, and an intelligent man will handle them perfectly after twelve hours' practice.

THEORY ON THE ORIGIN OF CLEAVAGE PLANES IN SANDSTONE.

BY THOMAS P. ROBERTS.

(Read at the meeting of the Engineers' Society, W. Pa., Nov. 18, 1890.)

That there is a great diversity in the texture, grain and cleavage lines of the sandstones used for building in this vicinity there is no doubt. The stone from some quarries may have an apparently uniform texture, color, etc., and yet be very difficult to split in more than one direction, while other stone of similar texture and composition may split well in two, or sometimes even in three directions, and such differences of qualities are sometimes found

within short limits of distance in the same stratum and quarry. Thus a given block may be easily split open on planes parallel with the "quarry bed," and be very refractory and uncertain on vertical lines crosswise, or lengthwise, so to speak, of the given strata. Such rocks as the last referred to, naturally produce more waste and require much more care and labor upon them not only at the quarries, but at the places where they are finally utilized in buildings. Our blue sands are chiefly of this class, though of late years a greater proportion of better stone is coming into use, even for work below the ground line, from the quarries along the Beaver river valley and other places. It is my observation, although it may not be correct, generically speaking, that this obstinate, cross, or curled grained is not so well adapted to withstand the action of frost as is most of the stone which possesses the merit of splitting well. In some instances, and I think it will be found as a rule for some localities which may hold good, that the refractory areas in otherwise good working veins of sandstone are impregnated with an extra proportion of earthy particles, and therefore not so well calculated to withstand the action of frost, at least this would be a fair deduction from the theory I propose very briefly to develop. It seems strange that some of the coarse open-grained sandstones of this region should withstand the action of frost better than others which are denser, heavier and harder to work when first exposed. We are apt to gauge the durability of stones so far as their ability to withstand frost is concerned by their absorbent qualities, though it may be that the open-grained stone, while very absorbent of water, may drain out and part with its moisture more freely as compared with the dense stones which have clay in their interstices, and which, when once soaked, must retain moisture longer. Coarse particles are apt also to present space for the inevitable expansion which ensues when solid freezing does occur.

The origin of cleavage planes in sandstones presents itself to my mind as an interesting speculation. If the correct theory is developed, and regarding this it does not appear to be involved with very abstract or abstruse considerations, it would be of considerable service to engineers and contractors in many ways, and I

think that in selecting stone heretofore for their constructions our engineers have not paid this subject the attention it deserves.

Primarily the theory of cleavage in stones was left to the lapidarists to solve, but I don't know that they have done more than to become experts in working them to the best advantage, and on materials that the engineer will probably never use extensively. In the building stones proper our masons are very frequently experts, but the mason in one district has to learn his trade over again if he moves out of it.

In discussing the question of the cleavage planes of the sedimentary rocks there has been a vast fund of information thrown open by the geologists, but as to whether this particular topic has been made the subject of special study with reference to the rocks of this part of the American continent I do not know.

The geologist tells us to begin with, and to end with, so far as the history of these great formations is concerned, that the earth's surface or crust frequently rose above and fell beneath the sea level. In other words, it is the generally recognized theory that all our stratified rocks were formed by the agency of water. I speak now of continental formations, for it is scarcely conceivable that the three miles thickness of stratified rocks over which Pittsburg is located for instance, could have been the result of deposits such as are now forming at the mouths of some of the great silt bearing rivers, although these latter may be very extensive so far as area is concerned. But while there are many plausible speculations as to the origin of the comminuted materials which made these rocks there is no longer any doubt that currents of water very broad, and of varying depths and velocities, were the prime factors in transporting them to their final resting place. The bottom velocities, and as I maintain, the direction of these currents, can now be determined to a certain extent by the texture and the grain of the stone. Thus it would appear reasonable to think that coarse conglomerates marked the positions of rapids, and for the extreme in the opposite direction, the slate beds, those areas where a feeble current at last came to rest and dropped its load.

The fundamental principle which governed Captain Eads in

devising his jetties at the mouth of the Mississippi, was laid down in the proposition that a specific velocity enables a current to transport a specific load, and that if that velocity be diminished or increased, as the case may be, it will drop a portion or pick up more load in proportion as its velocity is varied. The order of dropping a load is that heavy particles go first, and hence the assortment of materials with the series terminating in clear, calm water. Alternating currents, such as tides, or those produced by oscillations of the bed tending to disturb water levels, would appear to account for sand rocks in which clay is intimately mixed; or the same may be accounted for by intermittent changes of the velocity alone, for which intermitting changes many causes might be assigned. It is perhaps most reasonable to conclude that the individual strata of our sedimentary rocks were, for the most part, formed by currents flowing in one direction, though their intensity may have varied. In speaking, however, of currents in one direction, reference is here made to prevailing directions which, however, were subject to local disturbances and variations, for we find often in limited areas, sometimes within a few acres, rocks of the same genera, but varying greatly in thickness, texture and grain, which would indicate that there were projections on the older formation which resulted in eddies and swivels, which interfered with the even distribution and depth of the deposits.

Several years ago, in making a trip over the Monongahela river, in company with several army engineers, one gentleman casually remarked to me that as the current was practically imperceptible, the river being low at the time, in the wide deep pools of the dams, and the boat rounding to make landings, he was occasionally at a loss to say which was up and which was down the river; unless, indeed, he kept a constant watch from the guards. I told him I had been frequently non-plussed myself in that way in coming out of the cabin when the boat was at some unfamiliar landing place, unable to say at first glance which was up or which was down stream, but that I had learned by the appearance of the drift—such as logs, or trees, even twigs—and other objects which usually litter the banks, that they arranged themselves almost invariably with their larger, heavier and "dragging" ends up,

and their lighter, and more slender ends down stream. Exceptions were to be noted where eddies, caused by shore projections interfered with this arrangement. It must be true, then, that every particle of material in suspension in water when free to act will move along with its long axis parallel with the trends of the current. These particles, when not actually touching the bottom, must float with their heaviest end down stream, but the moment they catch the bottom they are rolled over or turned around, coming to rest with their light or tapering end down the stream. The shores of the Monongahela river are entirely of alluvial formation. That is to say the bottom lands are made up of deposits as the river gradually shifted from the base of the hills on one side to the other, and I assume that all these thousands of acres of rich sandy and clay loams, forming a stratum from 20 to 40 feet thick, were formed of material brought down by the river from its various headwaters, and that the particles composing this vast formation were arranged or assorted with their "points" down stream. If this theory be correct we should expect to find this material if it could now be transformed into solid rock, with a grain uniform in direction. I would liken the grain of stone where it is regular to the bristles on an animals back—feeling smoother in one direction than another.

After this material has been partially solidified in the river bank, or become, at all events, tolerably compact, it appears to be able to resist afterwards currents in the downward direction better than it will upward currents. At least I have always observed that eddies caused by even very slight artificial projections from these alluvial banks tend to produce scours in the banks below them. Near such projections there may be reactions of the water violent enough to account for this scouring action, but where, as in one case I know, the eddy is fully a half mile long, the cutting caving bank extends its whole length, while the upward current near the lower end is not nearly so great as the outside down current. I have thought that the sand "bristles" in the bank by being rubbed against the grain, presented a point for leverage sufficient for the current to overturn them and thus bring them

into suspension once again, something which the same current in the opposite direction could scarcely have done.

In the neutral centre of these eddies, after they have cut considerably into the banks, there is a tendency for circular or elliptical bars to appear, and these at low water will reveal to a careful inspection their materials in annular forms of varying degrees of fineness, the finer particles aggregated in the centre,—a cross-grained obstinate rock in embryo.

Not only can we infer that the water arranges particles of sand favorably disposed in one direction, but that these are deposited in more or less parallel layers, making what we might term horizontal cleavage planes, but that the particles when, as they are of nearly tolerably uniform size, fit together in a systematic arrangement, or a regular *alternating arrangement*, permitting of fracture on vertical lines, thus giving the remaining two possible cleavage planes. This idea could be illustrated with diagrams, but it is, perhaps, unnecessary; for it must appear reasonable to assume that, irrespective of the bond imparted to sandstones by silicious or iron compounds, its greatest strength to resist rupture would be on horizontal lines; hence, when it *must* split vertically, it will part on the lines of least resistance, and these lines will be minutely zig-zagged, following the ins and outs, or points and butts, of the alternately arranged particles. Where these particles are not alternately or systematically arranged, the desired vertical fractures are apt to lead astray and eventually spall off on curved lines, away from the largest mass and towards the point of least total resistance.

Some slate rocks present their only cleavage plane on lines vertical to their natural stratification. I would presume in this case that their materials were deposited in absolutely calm water, that is, that the stream charged with their material, having been perhaps suddenly arrested, proceeds to drop its load. In going straight down the particles strike the bottom and remain standing, with their "butts" or heavy ends down, which would afford only one kind of fitting together, viz., on vertical lines, but there could be no alternate arrangement, on this hypothesis, on horizontal lines. The cleavage plane would then follow on vertical lines

only, though why these planes should produce parallel leaves only is not so clear.

The fact, however, that we seldom, if ever, find vertical cleavage alone in those rocks where a *current* must be supposed to have deposited its particles gives strength to the idea I have sought to develop, viz., that it is only through the agency of currents that the further uniform and alternating arrangement of the sand particles in stone is possible, and which must exist before they can have the property of cleavage in more than one direction.

Discussion.

T. P. Roberts: I will mention for the benefit of some of the members, in reply to Mr. Winn's question, that the Monongahela river is to-day considerably wider than before the days of steamboating. I have some maps showing the river in 1833 and in 1838, and I have also seen maps of the Allegheny river made in 1828, and am therefore certain that such are the facts. There is a great deal in the subject of importance to the City of Pittsburgh, and it is now undergoing investigation on the part of the Chamber of Commerce.

Attention has been directed to the question as to what limitations we should make in regard to encroachments on the river bank, but I shall not undertake to discuss the subject to-night.

A Member: In what direction is the cleavage plane?

T. P. Roberts: I expected to illustrate my ideas on the blackboard, but finding it in use when I came was prevented from so doing. (Mr. Roberts then went to the blackboard and drew a sketch showing the grains of sand in their position in the sandstone, and explaining his ideas of the cleavage planes.)

He then spoke of the difference between sandstone in this connection and the flints of which arrow-heads are made, claiming as his idea that the Indians never made their own arrow-heads, but used those manufactured many years before their time by the Mound Builders who had the art of cutting the stones, an art so delicate that but few lapidarists could duplicate their works in flint, agate and obsidian. There are, therefore, no bogus flint arrow-heads in the market.

A short discussion followed participated in by W. G. Wilkins, P. Barnes, Isaac Winn and others. There being no further business the Society at 10 P. M. adjourned.

THOMAS P. ROBERTS,
Acting Secretary.

DECEMBER 16TH, 1890.

THE Society was called to order by President Scaife at 8.10 P.M. Directors Becker and Wilkins and in all 41 members present.

In the absence of the Secretary, T. P. Roberts was elected to to act as Secretary.

The President read a letter from Secretary Wickersham, who, on account of continued ill health, felt compelled to resign the Secretaryship. President Scaife thereupon communicated to the Society the action of the Board in the premises, by the passing of the following resolution :

Be it Resolved, That the Board of Directors accept with regret the resignation of Mr. S. M. Wickersham as Secretary of the Society, to take effect on the installation of his successor.

And be it further Resolved, That the thanks of the Board be tendered Mr. Wickersham for his faithful and valuable services to the Society during the past five years.

A. Dempster presented the following resolution, which was unanimously adopted by the Society :

Resolved, That the action of the Board, relative to the resignation of Col. S. M. Wickersham, be taken as the expression of the Society ; that we tenderly express our sympathy for him in his failing health, and indulge the hope that he may speedily recover and enjoy many days of happiness with his affectionate and loving family.

The President then read a letter from Capt. A. E. Hunt, enclosing some correspondence with Mr. John W. Weston, of the Western Society of Engineers, Chicago, relative to the headquarters of the engineering profession at the World's Fair, to be held

in Chicago, 1893. The following resolution was then presented, and adopted by the Society:

Resolved, That the Engineers' Society of Western Pennsylvania approve of the plan proposed by the Chicago Convention on Joint Headquarters and Engineering Congress for 1893, excepting in so far as it relates to financial assessments.

And Resolved, That this Society respectfully recommends the adoption of a method for raising money, by which all subscribing members in any contributing Society, and they only, be furnished by their Secretary with a card admitting them to the headquarters and accompanying privileges.

The election of new members being in order, the following persons, whose applications had been duly received and approved by the Board, were elected members of the Society of Engineers of Western Pennsylvania: W. C. Temple, Wm. L. Abbott, Theo. Tounelé, J. B. McIntyre, Robt. W. Lyon, Chas. M. Hall, Thos. Spencer, Robt. B. Carnahan, Jr.

The report of the Library Committee, to whom had been referred the question of permitting books or papers to be removed from the library, was presented by Prof. F. C. Phillips, Chairman. The report dwelt upon the difficulties in the way, and upon the liability of loss and damage to books which could not be replaced, should permission be granted members to remove them from the Society rooms. Mr. Metcalf called the attention of the Society to the fact that the gift of $1000, by the late Mr. Wm. Thaw, for the purchase of books, was with the tacit understanding that the Society's library was to be solely a reference library, and such had been the rule since the organization of the Society. On motion, the report of the Library Committee in regard to the matter was approved.

The Committee on Roads reported: "The preamble of the report, and the law proposed for legislative enactment by the Committee, was read at length."

In submitting the report of the Committee on Roads, Thos. P. Roberts said: "I can state that the Committee has had a number of meetings, and has gone over this matter thoroughly. They collected all the proposed acts of other bodies, the work of the

State Commission, the work that has been instituted by the University of Pennsylvania, particularly Professor Haupt. Our Philadelphia friends, however, seem to be off on scientific matters of road building, rather than preparing practical laws."

ANTES SNYDER: I understand from the Chairman of the Committee that they had formulated certain reasons, in which they had set forth in detail why they had presented this law, and I think it would be well for us to hear from them as to what they have to say before we have any general discussion.

T. P. ROBERTS: I omitted a great deal of the preceding portion of the paper that has been already published. It has been modified slightly, but the purpose was to ask the Society to approve this act so that we could have it printed immediately, and have copies enough to send to the members of the Legislature and to the members of the State Road Commission, and to other bodies that are working on this general object of improving roads. We think we have in that law a better general act regarding all the necessities of the case than any we have seen. We would like to hear any suggestions, but the Committee is very anxious to have the matter finally disposed of to-night, but of course if the Society does not wish to take any further action in the matter, it can be held over. There is a great deal to be said on the general merits of the question.

ANTES SNYDER: It is not the general merits of the question that is now before the Society. It is the general merits of this act. Can the members of this Society from merely hearing that act read over once discuss it intelligently?

T. P. ROBERTS: I will state that nine-tenths of that act was once before approved by this Society. The modifications are in type-writer print, while the main portion is in detail, for instance, in connection with the use of roads by pipe-lines. We have supplied little omissions of that kind in making the law more effective, but otherwise it is substantially the same law as was presented a year ago, and which was approved and ordered to be printed by the Society at that time.

ANTES SNYDER: The original law may have been harmonious in all its parts, but every modification, every addition made, would

affect something else in the law, and it may not be the same thing. I noticed one point. The highway fund is to be expended by the commissioners in the improvement and repair of highways. Now where is the money to come from to open new highways. There will be new highways to open. I think there are a good many little points like that that no man can see through—that we cannot comprehend, but need to study for some length of time. They do not occur to you at once, these little inconsistencies. What we want is to get a perfect law. I do not want this Society to send a crude thing down to Harrisburg. It seems to me if this whole matter was printed and furnished to the Society at the next meeting we could discuss it intelligently.

J. F. Wilcox: I noticed in a report of Superintendent Warner, of the workhouse, the use of convicts on the roads, and I had occasion to pass over some of the roads in Georgia that are built by convict labor, and I would like to know what bearing this has on this question. I would like to ask the committee if they considered this matter in the preparation of the report.

T. H. Johnson: I would say in reply to that, we have not thought it worth while to make a provision for the use of convict labor. The work done at the workhouse, as I remember the figures, cost in the neighborhood of $4500 per mile, which is about twice the sum a good turnpike ought to cost.

T. P. Roberts: We discussed that question of convict labor at several of the meetings, and the unanimous opinion of the members was that it would not be advisable to consider it. The sight of convicts on the county roads would be enough to remind us of the early days when there was tyranny in this and other countries. And the further fact also was dwelt upon that, outside of a few of the larger counties, there are but few prisoners to do the work. The average county has probably ten convicts, of which number not more than two or three are able-bodied men. There are very few really able-bodied men in the prisons. I have seen several papers written on that subject. It is possible the county commissioners could arrange to have the stone broken in the jail-yard. Such things as that could be done under this law.

Antes Snyder: There would be nothing to prevent the

superintendent of a workhouse undertaking a contract to build a portion of a road?

T. P. Roberts: No, sir.

Further consideration of the report was postponed, and it was ordered to be printed for immediate distribution among the members, and that final action be taken at the next meeting.

H. D. Hibbard then read the following paper:

DEFECTS IN DESIGN OF OPEN-HEARTH STEEL-MELTING FURNACES.

It is not intended in this paper to cover the whole field of possible or actual defects which may exist in the many parts of an open-hearth furnace. Those here considered have all come under the writer's observation in regular work, and are all he can recall at present.

In some of the cases the means used to counteract the defects will be pointed out. In many the obvious cure is apparent as soon as the true state of affairs is recognized. Some apply only to furnaces fired with artificial, not natural, gas.

They are enumerated below with remarks on each following in order.

They are:

1. Too small gas-ports and ducts.
2. Too small air-ports and ducts.
3. Too large gas-ports.
4. Too large air-ports.
5. Too small regenerators.
6. Too closely-piled checker-work.
7. Too small flues and stack.
8. Working hearth at too low a level.
9. Gas- and air-ports beside each other.
10. Regenerators in which draft is horizontal.
11. Too thin walls and brickwork.
12. Use of clay bricks.
13. Circular hearths.
14. Furnace with ends unlike.

1. *Too Small Gas-ports and Ducts.*—The trouble from this comes, of course, because enough fuel cannot be introduced into the furnace, and the melter complains that the furnace doesn't work well. Stirring up the gas-makers and calling for more gas doesn't help it much. A furnace I have had in charge improved its working qualities after 150 or 200 charges, when the gas-ports and ducts had been enlarged by the fluxing of their sides by the oxide of iron carried over from the working-chamber, allowing freer passage to the gas. A furnace which has been through this experience will, of course, have these passages made larger at the next general repair.

2. *Too Small Air-ports and Ducts.*—This is a serious defect when present, and will not usually correct itself as the furnace grows older in use, as will the preceding, for the reason that the heat is less in the air-ports and ducts. Their lower temperature is because of their greater distance from the working chamber, they being usually nearer the cold outside of the furnace, and, being longer, do not get their share of the outgoing gases from the hearth. All of these that can find room seek the more direct route through the gas regenerator.

This trouble is incurred, as is the preceding, by not taking into consideration the great expansion of the ingoing gas and air, due to the high temperatures they acquire in traversing the hot flues and regenerators. Air increases one volume for every 273° C. it is heated, and, as it doubtless enters the hearth at at least four times that temperature, at least four times as much area of cross-section must be provided for it in the ports near the hearth as it has at the regulating valve where it enters the furnace.

If this case exists, care must be taken to keep the amount of gas in the furnace down to that which the entering air will burn effectively. Any excess of gas beyond this will cool the furnace. If, with this precaution, the results are not good enough the furnace must be altered. Blowing in air as a cure is not advisable, though it might be done if the gas-ports were too large, so that the out-going gases could find vent to the chimney without too strong draft being required. Too strong draft would draw an unusual amount of cold air into the ducts and regenerators, through

the crocks in the brick-work cooling them unnecessarily, thus injuring the working of the furnace.

3. *Too Large Gas-ports, and* (4) *Too Large Air-ports.*—We will consider these together, because, if they exist together in the same furnace, they tend to counteract each other to some extent, but, if only one is too large, trouble arises demanding attention.

The effect of too large ports for either gas or air is that these ingoing fluids, seeking naturally the shortest route, will fill the ducts and ports nearest the front of the furnace, where they enter to their full capacity, so that those on the back side receive little or none. An even distribution of gas and air over the hearth is desired; but, if either has too great passages, it will rise too plentifully at the front, and, flowing into the hearth, give a badly distributed flame, and, of course, bad work. In the portions of the hearth where air is too plentiful, too much waste of stock occurs, and where gas is in excess, a dull smoky flame too cold for good melting is found.

To remedy these defects the ports nearest the front, or the bridge-wall, if one is used for the air to pass over, must be partially closed, which may with many furnaces be done, when running, by loose bricks placed in by means of hooks. The bridge-wall is easily built up from a hole opened in the end-wall of the furnace, and bricks can be added on the front side until a regular distribution of air obtains.

Another way of guarding against the effect of too large air-ports in a furnace using producer-gas is to have the gas-ports brought nearer the front side of the hearth. This will also counteract the effect of any air drawing in around the doors, which too strong chimney draft would cause. The excess of air in front is met with the excess of air, and, if the latter is not too great, fair distribution of the flame results.

A furnace cannot be affirmed to have too large gas- or air-ports until it is up to full melting heat. When first started, and the entering gas and air are quite cold, the front port or ports may seem to be doing all the work, but when these inflowing gases are hot, and, therefore, of much greater bulk, all the ports may be used

to their full capacity. An excess of capacity in the ducts does no appreciable harm if the ports are of the right size.

5. *Too Small Regenerators.*—These cause waste of fuel, because of the heat lost in the outgoing gases due to the high temperature at which they escape into the chimney-flue. All heat which passes the reversing-valves is lost. The valves themselves suffer from the high temperature to which they are thereby exposed, and often require repairs or renewal from this cause. With ample regenerators they may still be damaged by the use, or rather misuse, of too much gas in the furnace, which prolongs the flame down into the regenerators, and even to the valves. I have seen them red-hot from this cause, which, of course, is not the fault of the designer, but the larger the regenerators the less likelihood of such trouble.

Too large regenerators will hardly be put in. I never heard of any trouble laid to that cause, nor can I think of any reason to expect trouble from using any large size which would seem in the least reasonable. By making them large they are less damaged by heat, give longer runs to the furnace and economize fuel.

6. *Too Closely Piled Checker-Work or Regenerator Bricks.*—This often comes from an attempt to correct the defect of too small regenerators. The result is naturally the partial stoppage of the gases passing through either at once when the furnace is new, though it is seldom as bad as that, or after running a greater or less time proportional to the degree of the defect. While the furnace is operated the spaces in the checker-work of the regenerators are gradually filled with oxide of iron in the form of dust, which is carried over by the draft, some being deposited in the regenerators and flues and some issuing at the top of the chimney at times as a light-brown smoke. In the hottest parts of the regenerators this oxide of iron fluxes the bricks, the molten material formed runs down and chills in the lower and cooler parts, and so hastens the stoppage of the passages for the gases. When these passages are not large enough at first, due to the defect we are considering, a short run only can be made before a shut down is forced.

7. *Too Small Flues and Stack.*—This defect requires, of course,

but little consideration here, as after it is recognized the cure is obvious.

The flues between the regenerators and reversing valves and the chimney flue collect some of the oxide of iron brought over from the hearth, the deposit being heavier the nearer the furnace. This deposit will in time grow large enough to interfere with the working of the furnace by restricting the flue area, unless there has been ample excess provided for it in the furnace design.

The stack, if large enough at first, will remain so, as it is not liable to stoppage.

It should be borne in mind, that as the drawing power of a stack depends on the temperature of the gases within, that one which is ample with small regenerators and consequently hotter escaping gases may be not high enough with larger regenerators, which cool the gases much more before they reach the stack. More height, but not more area of cross-section is needed in the latter case. In fact, less sectional area would serve, as the volume of escaping gases, due to their lower temperature, is less than in the former case.

8. *Working Hearth at Too Low a Level.*—This is with reference to the point of entrance of the air and not the ground or working floor, though it usually will be to the ground also, as the air nearly always enters at about its level.

The point is as follows: A regenerative furnace, to work well and be under complete control, must have both gas and air introduced to the working chamber under pressure, the chimney being used only to take away the waste gases as fast as formed. Bad work, and especially heavy waste of iron will result, if the chimney draft is used to draw air or gas into the furnace. When it is used at all to assist in this way, it will also draw cold air in through the cracks around the doors and in the brickwork, which will injure the heat of the furnace.

Gas from producers is forced in by the pressure of the steam-blast under the fires; natural gas, by the pressure from the wells. Therefore the gas needs not this precaution, but with the air the case is different. In a furnace with a high-working hearth, having in consequence high regenerators and a very considerable

difference in level between the air-valve and hearth, there is a column of air of that height, strongly heated and rarefied, which causes it to rise and flow into the working chamber unaided.

When, from any construction, this column of heated air is too low, so that an outward pressure or plenum cannot be maintained in the working chamber, together with a suitable flame, air should be blown in preferably by a fan-blower. Indeed, the working of many, if not all furnaces, would be improved by being supplied with air under greater pressure than it usually has.

9. *Gas- and Air- Ports Beside Each Other, or Arranged so as Not to Bring the Air Into the Working Chamber Above the Gas.*—The air should enter above, because this keeps the flame down on the charge, which is thereby melted faster and away from the roof, which is then not melted so fast, two desirable conditions to maintain.

The incoming air, though heated, is still colder than the other gases in the working-chamber, and therefore tends to flow down along the bottom of the chamber, as does cold air entering a warm room. If there is no gas below to intercept and burn it, undue oxidizing conditions will exist around the charge, and too much waste and its consequent trouble ensue. The chief reason though for introducing the air above the gas has been the preservation of the roof, though this is becoming less urgent as higher roofs become common. Better combustion also results from the intimate mixture of the gas and air caused by the latter falling into and through the flame from above.

10. *Horizontal Regenerators.*—By this is meant those in which the gases flow horizontally instead of vertically or diagonally, as is usual.

In horizontal regenerators, the outgoing gases, being hotter than the chamber, naturally flow out along the upper levels, while the ingoing, being colder, flow in along the lower levels. As a consequence, much of the efficiency of the regenerators is lost. The top keeps hot and the bottom cold, comparatively speaking. The waste gases reach the chimney hotter and the ingoing reach the hearth colder than the size of the regenerators ought to permit.

If the regenerators are built as flues and their cross-sections are

so small that the whole area is needed to convey the moving gases, this evil is avoided; but another one is met, namely: that as soon as the effective area is reduced by the deposition in the regenerators of dust carried from the hearth, they will be too small for their purpose.

Enlarging the regenerators will not greatly increase their effectiveness, if they are shown to be inadequate, by the high fuel consumption and high temperature of the waste gases, as long as the principle of the horizontal draft is adhered to.

11. *Too Thin Walls and Brickwork.*—It is a question just how thick these should be, but in general they should be so thick that working about the furnace is reasonably comfortable as regards heat, even in summer. This is especially applicable to the doors, which are sometimes bricked up only 2½ inches thick, making it warm for the workmen.

As with high roofs and increased skill in judging the temperature of the hearth by the melter, the life of the furnace, and especially of the roof, is being prolonged, the writer thinks the time has come for increasing the thickness of the roof over the regulation 9 inches. More bricks, or, perhaps better, an equivalent thickness of sand, which will rise and fall with the roof, would save much of the large amonnt of heat now lost by conduction through the roof with an equivalent saving of fuel.

12. *The Use of Clay Bricks* is, in the light of current practice, to be considered a defect. Campaigns of a thousand heats or over being at least occasional, and of five hundred quite common, clay bricks giving a hundred are dear at any price, or even no price.

13. *Circular Hearths.*—The evident faith of designers of these hearths was that the flame would spread itself out as it entered the hearth, so as to insure an even heating in all parts. Instead of this, however, we find the flame taking its straight path through the chamber, melting a swath through the charge at first, the stock out of its course melting with heavy waste afterward. Probably no more of these will ever be built, at least until those who have used them have left the steel business.

14. *Furnace with Ends Unlike.*—This is, of course, very unusual, due to the local situation in the shop, only one case being

known to the writer. The regenerator at one end of a furnace was cut off to make room for another furnace, the equivalent regenerative capacity being secured in another way. The chief trouble came from the difference in draught in the two ends. As a consequence, seven different motions were required to reverse the furnace, viz.: (1) shut off gas; (2 and 3) throw the two reversing-levers; (4) turn on gas at the other end; (5 and 6) adjust two air-valves; (7) adjust chimney damper. Natural gas was used. Still the furnace was made to work after a fashion, though at the first opportunity it was restored to its original form, as the room seemed to be used more profitably that way.

To conclude, a furnace may have several of these defects, which perhaps, will only be recognized successively. As one is remedied it brings into prominence another which, being righted, may develop a third, and so on. Much time and money are usually wasted before a furnace defectively designed is brought into proper shape and has suitable proportions all through for good work. Frequently entire rebuilding would be the cheapest cure in the end.

Some furnaces may work well for short runs, and only show the effect of bad design when, due to increased skill of the melters, long campaigns become possible were the furnace rightly built. The proof of a furnace is, of course, its record in the hands of competent men, and one which has melted five hundred heats at a fair rate and with good economy of fuel ought to be altered with extreme caution, if at all.

Discussion.

Wm. Metcalf: I noticed one or two points in the paper which were especially interesting to me. I listened a long time for the author to mention the flues. He finally did mention inadequate flues. I found a good many years ago that the Siemens furnaces, as designed or built according to the designs furnished by the patentees or the agents in this country, never worked quite satisfactorily. I do not speak now of the open hearth, because I do not use them, but crucible furnaces. The difficulty was aggravated there. It was very difficult to get a good flame in the farther

end of the furnace. After a great deal of study and bothering with the furnaces, I came to the conclusion that the whole trouble was with the flues below the checker-work, and in designing the furnace, which is probably the largest furnace of this kind in the world, I think certainly is, a sixty-pot crucible furnace, fifty feet long, the farthest melting hole is fifty feet from the valves. The question of getting a furnace of that length sufficiently hot at the farther end, was a serious difficulty. After a careful study, I designed each flue one and a half times the size of the total area of all of the ports. The gas flues were perhaps one and a half times the size, and the air flues twice the size, making the flue under the checker work, fifty-four inches deep. That is the best furnace we have ever had and the most economical, and the melting hole fifty feet from the valve is as hot as the nearest hole to the valve. I think that insufficient flues under the checker work in many designs I have seen in open-hearth furnaces, is one of the most serious causes of imperfect work of any of the defects mentioned, for the reason that the gases will then take the most direct course, fill up the front ports, and you never get the back ports hot, whereas, if there are large valves and plenty of room in the flues for the gas to flow in, it will fill all of the ports, and you have your furnace nicely and evenly heated.

The only remark in the paper that I would criticize is that in reference to the roofs. I think if the author tries it, he will find that probably the standard nine-inch roof is a happy accidental medium. I have tried when they became a little defective to patch roofs up by putting a cover on, and in every case it was a certain failure. Where a little sand or fire-clay has been left on the roof by the bricklayers, the roof will get red-hot at that point up to the sand, and in a short time the roof will give way and come down, so that now whenever we put a roof in our furnaces, I am always careful to have them swept clean. I think that would be the effect of sand on the roof. I doubt very much whether a thirteen inch brick wall would do at all, unless the bricks were made whole, thirteen inches, because $4\frac{1}{2}$ inches over the 9 inch cover would let the lower arch get red-hot, and the bricks would be destroyed very rapidly and come down. On

the other hand, if they were made 13 inches long they would be very cold on top. My impression is that a change in temperature would cause the bricks to drop out in lumps, and crack as they do now frequently in the 9-inch roofs. And further, when the crown of the arch was burnt thin, the arch at the sides would be so much heavier that they would break the roof in.

I have not had much experience with open hearth furnaces for melting steel, but have had for melting iron, and that is about the way they act.

J. W. LANGLEY: In speaking of some of the defects of furnaces, I notice that the writer said nothing about the possible defect of too large size. I would like to ask if he has arrived at any conclusion as to what is the maximum size to which an open hearth furnace can be built and run successfully.

H. D. HIBBARD: I do not know that that point ought to be included under this head. I think that question is one entirely to be governed by the size of ingots it is desired to make. If you want 50-ton ingots, make 50-ton furnaces; if you want 100-ton ingots, make an equal size furnace. The size is based on the size of ingots required, the furnace being to some extent in proportion to the size of ingots to be cast. I think it would be practicable to build 50-ton furnaces and cast 100-ton ingots. By any system of casting I know of, it can be done successfully if the steel be at the proper temperature at the beginning, the furnace being in proportion. Otherwise, it would be too cool at the end, and if the ingot had the proper temperature at the end, then the cast at first would be too hot, and we all know what that means, the steel would be of inferior quality. My answer to the question would be that the furnace should be definitely proportional to the size of ingots desired.

J. W. LANGLEY: You think a 100-ton furnace could be built?

H. D. HIBBARD: Yes, sir; I do. I say entirely practicable. There is one difficulty with very large furnaces which comes in, and that is that the men who work them are no larger than those who work the smaller furnaces, and the tools necessarily become so large and so heavy that it is rather troublesome to keep the

bottom in good shape and repair, while all the other work around the furnace is increased also, but I believe even then it is possible with machinery of some kind devised for performing the operations which are difficult. With the proper machinery we could charge 100-ton furnaces as well as smaller sizes.

T. P. ROBERTS: Would there be any economy in the large furnaces?

H. D. HIBBARD: I think that is a question, too, depending on what you call economy. If you want large quantities of large ingots there is economy in large furnaces in every way, economy in labor. I think there would be some economy in fuel the larger the furnace, provided it were properly proportioned.

W. METCALF: I stated a few moments ago that the large crucible furnace I built was the best and most economical one we have. I will say that that furnace will melt crucible steel with 25 per cent. less fuel than any furnace we have, and I have never seen a furnace too big. The larger you get them the more economical they are. There is a limit, I suppose, but I have never seen a furnace which would not be improved by making it larger.

I would like to show the evolution of the old reverberatory furnace. (Mr. Metcalf here illustrated on the blackboard the old type of furnace, and also described the improvements made in the same.)

This (No. 1) is the first style of furnace I have any knowledge of. It has a pitched roof, and by some ingenious means they had the tap hole the farthest away from the fire. I presume it took about twenty bushels of good coal to melt a ton of iron. The first change made was the moving of the tap hole nearer the bridge-wall, so that the pool of melted iron would be nearest the heat. The next, in order to get a larger heat, was to straighten up the crown, and then, in order to get still larger heats, the crown was straightened up in this way (illustrating), and the kitchen was made larger above the bridge-wall. This form, lastly, occurred. At the Fort Pitt Foundry, during the war, one furnace had to be repaired. It interfered with a passage-way, and to get out of that trouble we cut the stack off and put it on the side. We were told there would be a cold corner at the back end. We tried it, and, in-

stead of a cold corner, this furnace began to melt the iron at this end as quickly as any other, and much quicker than any furnace we had. Then we built all the largest furnaces in this form, the flame coming out at the side. It became necessary to have a very large capacity, and the question was raised as to whether we could build a furnace that would melt forty tons. This is a direct answer to the question about the size of the furnace. One of the army officers and some of the people around the foundry thought that a large mass of iron could not be melted without ruining it. Our necessities were so great that it was finally decided to build it. The kitchen of that furnace was 7 feet high, 11 feet wide, 17 feet long. These are the clear dimensions. It was just a common coal furnace. It was quite common to charge 40 tons of iron in this furnace. We put a whole gun in sometimes. We would start the furnace cold in the morning, and melt the charge in from 3½ to 4 hours.

One year I took a very accurate account of the fuel used in these different furnaces. I weighed every pound of coal that went to every furnace in the place. The result, as near as I can remember, was as follows: This furnace, which we will call No. 3, took about 16 bushels to a ton of iron. This was a 10-ton furnace. The 15-ton furnace would melt with about 13 bushels. The 25-ton furnace, made in the new shape, would turn out a full melt with 7 to 8 bushels. Remember, these are actual weights taken for the whole year. The furnaces ran every day, excepting when down for repairs. The 40-ton furnace took 4½ to 5½ bushels per ton. That is the advantage of the big furnaces.

A. Snyder: Did you notice any great saving of the loss in melting?

W. Metcalf: We had no opportunity to observe that. We had to get enough in every time. I remember the figures in round numbers. This was about the way the furnaces acted. That furnace had a two feet rise in the crown here, and that had a great deal to do with the saving of fuel. We raised the crown and gave room for combustion. Of course there is a limit, but as far as my experience goes I have never seen a furnace too large.

A. Snyder: How about the relative life?

W. Metcalf: That big furnace would run about as long as the

others. The average life was only about six or eight weeks, because, being coal-furnaces, we had to make new sand-bottoms every day. They were charged cold every morning, and then fired up with all the draft of a tremendous stack. The stack to that big furnace was 11 feet in diameter and 70 feet high. Sometimes the fireman would neglect his fire, and the grate-bars would begin to vibrate under that tremendous draft, making such a noise that several hundred feet away you could not hear the noise of the machinery in the mill; it seemed like a wizard's shop, all life and no noise.

J. HOPKE: I would like to ask Mr. Hibbard's opinion of the style of roof in the so-called circular furnaces. The Lash furnaces use natural gas. The gas goes in a pipe here (illustrating), and then there is a roof swinging directly over this neck. The flame strikes this projection here, and it burns away very quickly.

H. D. HIBBARD: I do not know that I have had experience with that type.

T. M. HOPKE: I know of one furnace in which they got out seven heats, and then the projection was burned away entirely. They had to put an entire new roof on.

W. METCALF: I cannot believe those projections are any use. In a conversation with Dr. Wedding, when here with the foreign engineers, he stated that they run little furnaces in Europe of a bee-hive shape; but after my experience with the big furnace I never had any desire to use a roof going any way but up.

T. M. HOPKE: It may be interesting to some of the members to mention a little conversation I had to-day with a gentleman who tells me that he has an open-hearth furnace—I think a 5-ton furnace—which makes an excellent steel without regenerating at all. He heats his air to the temperature of 6700°, and brings that through a burner. He mixes that thoroughly with the gas, and with that mixture he gets perfect combustion, has a better temperature, and has better control of the furnace, and yet does not regenerate at all. He says that the pipe never gets above a dull-red heat.

H. D. HIBBARD: I think the furnace just mentioned is hardly correctly-styled as not regenerative. The air is heated by the waste heat of the furnace. I would not approve of any system of re-

generation in which the heat is conducted through anything; that is, in comparison with the principle of the Siemens regenerative furnace, which effects its regeneration by the means of reversing, with which we are all familiar.

W. Metcalf: Did he give you any data as to the endurance of that furnace?

T. M. Hopke: The furnace has only been running a short time but he thinks there is no reason why it should not last for a very long run.

T. P. Roberts: What is the fan-pressure developed for these furnaces?

H. D. Hibbard: I never measured it, but it is not great. I presume a pressure of 6 inches of water would be ample. I know of one case where a fan-blower was put in for that purpose coupled to run a thousand revolutions. That would be a pressure of about one-half pound, or about one foot of water in round numbers. That was too big entirely. It was reduced to 400 revolutions, which was even found greater than was required. I presume, therefore, it would be less than six inches—probably from four to six inches.

W. Metcalf, Chairman of the Committee on Nomination of Officers for the ensuing year, reported that the following-named gentlemen had been nominated:

For President, Thomas P. Roberts; for Vice-President, A. E. Hunt; for Secretary, J. H. Harlow; for Treasurer, A. E. Frost; for Directors, two years, G. S. Davidson, Thos. H. Johnson.

At 11.15 p.m., the Society adjourned.

T. P. Roberts,
Secretary pro tem.

OFFICERS FOR 1891.

PRESIDENT,

One Year—T. P. Roberts.

VICE-PRESIDENTS,

Two Years—A. E. Hunt. One Year—Phineas Barnes.

DIRECTORS,

One Year—R. N. Clark. One Year—W. G. Wilkins.

Two Years—Geo. S. Davidson. Two Years—Thos. H. Johnson.

SECRETARY,

One Year—James H. Harlow.

TREASURER.

One Year—A. E. Frost.

COMMITTEE ON LIBRARY,

F. C. Phillips, Chairman, L. B. Stillwell,
Charles Davis, E. B. Taylor, H. D. Hibbard.

COMMITTEE ON ROOMS,

R. N. Clark, Chairman, G. S. Davidson, E. V. McCandless,
Wm. Thaw, Jr.

COMMITTEE ON PROGRAMME,

W. G. Wilkins, Chairman. Emil Swenson, T. M. Hopke,
Henry Aiken, H. P. DuPuy, P. Barnes.

LIST OF MEMBERS.

Date of Membership.		
Dec. 16, '90.	Abbott, W. S.,	48 Fifth Av., Pittsburg, Pa.
May 21, '80.	Aiken, Henry,	508 Lewis Building, Pittsburg, Pa.
Mar. 20, '88.	Aikman, Edw. G.,	115 Broadway (Room 95), New York.
Oct. 20, '85.	Albree, C. B.,	18 Market St., Allegheny, Pa.
Apr. 20, '80.	Amsler, Chas., M.E.,	Bissel Block, Pittsburg, Pa.
Dec. 16, '84.	Anderson, J. W.,	45 Fremont St., Allegheny, Pa.
Jan. 6, '80.	Armstrong, Edw.,	Supt. Alleg. Water Works, 160 Webster Ave., Allegheny, Pa.
Jan. 6, '80.	Armstrong, H. W.,	Metcalf, Paul & Co., Pittsburg, Pa.
Jan. 18, '87.	Arms, W. F., M.E.,	R. & P. C. & I. Co., Punxsutawney, Pa.
Nov. 20, '88.	Arras, John W.,	P. O. Box 485, Pittsburg, Pa.
Apr. 15, '60.	Ashworth, Daniel,	Hamilton Building, Pittsburg, Pa.
Feb. 21, '82.	Aull, W. F., C.E.,	Manager Denny Estate, Box 91, Pittsburg, Pa.
Jan. 6, '80.	Awl, John L.,	Mgr. Monong. Incline Plane, Pittsburg, Pa.
Sept. 20, '87.	Bailey, Chas.,	Reliance Steel Casting Co., 36th St. and A. V. R. R., Pittsburg, Pa.
Sept. 16, '84.	Bailey, Jas. M.,	Mfr. Sligo Iron Works, Pittsburg, Pa.

Date of Membership.		
Jan. 15, '84.	Baker, Chas. H.,	Metcalf, Paul & Co., Verona, Pa.
May 18, '84.	Bakewell, Thos. W.,	Bakewell Building, Pittsburg, Pa.
June 19, '88.	Bakewell, Wm.,	110 Diamond St., Pittsburg, Pa.
Apr. 17, '88.	Barbour, Geo. H.,	20 Portland Block, Chicago, Ill.
May 19, '85.	Barnes, Phineas,	Jones & Laughlins, Ltd., Pittsburg, Pa.
May 20, '90.	Barret, J. H.,	134 Jackson St., Allegheny, Pa.
Nov. 21, '82.	Bates, Onward,	Rand & McNally Bldg., Chicago, Ill.
Jan. 6, '80.	Becker, Max J.,	C. Eng., P., C. & St. L. Ry., Pittsburg, Pa.
Jan. 20, '85.	Beckfield, Chas.,	804 DuQuesne Way, Pittsburg, Pa.
Nov. 19, '89.	Bell, W. G.,	P. O. Box 976, Pittsburg, Pa.
Dec. 18, '83.	Benney, Jas.,	Emsworth, Pa.
Jan. 6, '80.	Bigelow, E. M.,	Chf. of Dept. of Public Wks., Pittsburg, Pa.
Feb. 19, '89.	Billen, C. E.,	Supt. Bridge & Const. Dept. Penna. Steel Co., Steelton, Pa.
Mar. 18, '91.	Black, S. W.,	99 4th Ave., Pittsburg, Pa.
Sept. 18, '83.	Blank, Hugo,	Chemist, 77 4th Ave., Pittsburg, Pa.
Jan. 11, '89.	Blaxter, G. H.,	Allegheny Co. Light Co., Pittsburg, Pa.
Mar. 18, '84.	Bole, W. A.,	Supt. West'ghouse Mach. Co. 25th and Liberty Sts., Pittsburg, Pa.
Jan. 6, '80.	Borntraeger, H. W.,	Keystone Bridge Co., Pittsburg, Pa.

Date of Membership.		
Apr. 19, '81.	Boyd, Henry A.,	National Tube Works, McKeesport, Pa.
Mar. 18, '84.	Brashear, John A.,	Optician, Observatory Ave., Allegheny, Pa.
Feb. 17, '91.	Braune, J.,	Keystone Bridge Co., Pittsburg, Pa.
Nov. 16, '80.	Bray, Thos. I.,	Warren, O.
Apr. 19, '87.	Breen, H.,	Keystone Bridge Co., Pittsburg, Pa.
Jan. 6, '80.	Brendlinger, P. F.,	79 Warburton Ave., Yonkers, N. Y.
Jan. 19, '86.	Brockett, Alonzo H.,	Mellor & Hoene, Fifth Ave., Pittsburg, Pa.
Jan. 6, '80.	Browne, Geo. H.,	Supt. Water Works, Pittsburg, Pa.
Jan. 6, '80.	Brown, W. R.,	City Engineer's Office, Pittsburg, Pa.
Apr. 18, '82.	Brunot, H. J.,	Greensburg, Pa.
Jan. 18, '87.	Buente, C. F.,	Stone Contractor, Duquesne Way & 10th St., Pittsburg, Pa.
Jan. 6, '80.	Bullock, W. S.,	Taylor & Bullock, Pittsburg, Pa.
Sept. 21, '80.	Burgher, Rutherford,	Treasurer Kidd Steel Wire Co., Ltd., Harmarville, Pa.
Jan. 19, '86.	Cadman, A. W.,	Brass Manufacturer, Pittsburg, Pa.
Dec. 20, '87.	Campbell, Hugh C.,	187 Sandusky St., Allegheny, Pa.
May 23, '82.	Camp, Jas. M.,	Duquesne, Pa.
Feb. 20, '83.	Carhart, Danl.,	C. E., Prof. Math. and Eng., Western University, Allegheny, Pa.
May 19, '85.	Carlin, Thos. H.,	Machinist, 186 Lacock St., Allegheny, Pa.

Date of Membership.		
Nov. 18, '84.	Carlin, David,	Mgr. W. G. Price & Co. Iron and Lead Works, 5th Ave. and Price St., Pittsburg, Pa.
Dec. 16, '90.	Carnahan, R. B.,	339 Shetland Ave., Pittsburg, Pa. E. E.
Apr. 20, '80.	Carnegie, Andrew,	Steel, 55 Broadway, New York.
Mar. 18, '91.	Caughey, E. G.,	19 North Ave., Allegheny, Pa.
Sept. 18, '83.	Chambers, J. S., Jr.,	C. E., Box 212, Trenton, N. J.
Feb. 17, '80.	Chess, H. B.,	Chess, Cook & Co., Nails and Tacks, Pittsburg, Pa.
Nov. 21, '82.	Clapp, Geo. H.,	Chemist, 95 and 97 Fifth Ave., Pittsburg, Pa.
May 19, '89.	Clark, Louis J.,	Western Pa. Phonograph Co., 146 Fifth Ave., Pittsburg, Pa.
Jan. 18, '88.	Clark, R. N.,	Rustless Iron Co., 32d and Smallman Streets, Pittsburg, Pa.
Oct. 16, '83.	Coffin, Wm.,	Draughtsman, Franklin St., Allegheny, Pa.
Apr. 19, '87.	Colby, J. A.,	Wilmington, Del.
Feb. 22, '81.	Cooper, Chas. H.,	Bakewell Building, Pittsburg, Pa.
Dec. 20, '81.	Cooper, John W.,	Draughtsman, Pitts. Locomotive Works, Allegheny, Pa.
Nov. 19, '89.	Cornelius, W. A.,	Hazlewood, B. & O. R. R., Pittsburg, Pa.
Sept. 21, '80.	Curry, H. M.,	Lucy Furnace Co., Pittsburg, Pa.
May 23, '83.	Danse, L. O.,	Architect, Webster Ave. and Morgan St., Pittsburg, Pa.
June 19, '88.	Davis, Chas. H.,	1026 Pine St., Philadelphia, Pa.

Date of Membership.		
Jan. 6, '80.	Davis, Chas.,	County Eng., Court House, Pittsburg, Pa.
Dec. 21, '80.	Davison, Geo. S.,	Westinghouse Building, Pittsburg, Pa.
Feb. 17, '91.	Deforth, John M.,	Keystone Bridge Co., Pittsburg, Pa.
Jan. 6, '80.	Dempster, Alex.,	C. E., Coal Operator, Standard Bldg., Pittsburg, Pa.
Jan. 6, '80.	Diescher, Samuel,	M. E., Hamilton Building, Pittsburg, Pa.
Apr. 19, '81.	Dixon, C. G.,	Contractor, 34 Park Way, Allegheny, Pa.
Nov. 15, '87.	Dobson, Thos. H.,	Penn P. O., Lancaster Co., Pa.
Apr. 15, '84.	Dravo, H. G.,	Iron Mcht., 413 Wood St., Pittsburg, Pa.
Jan. 18, '88.	DuBarry, H. B.,	Office Ch. Eng. Pa. Lines, Pittsburg, Pa.
Jan. 22, '89.	DuPuy, H. P.,	Westinghouse Building, Pittsburg, Pa.
Sept. 16, '90.	Davis, A. R.,	Edgar Thomson St'l W'ks, Braddock, Pa.
Oct. 21, '90.	Dravo, E. T.,	49 Fifth Ave., Pittsburg, Pa.
Nov. 18, '90.	Duxrud, Peter,	Park Bros., Pittsburg, Pa.
Jan. 18, '81.	Eckert, E. W.,	C. E., 34 West 38th St., New York.
Jan. 6, '80.	Edeburn, W. A.,	Eng. and Surveyor, Bakewell Building, Pittsburg, Pa.
Mar. 18, '91.	Edwards, J. P.,	Uniontown, Pa.
Jan. 6, '80.	Ehlers, Chas.,	City Eng., No. 8 City Hall, Allegheny, Pa.
Feb. 27, '88.	Engle, Geo. W.,	Eng. Gen. Office. Penna. Co., Pittsburg, Pa.
Sept. 19, '82.	Engstrom, F.,	Engineer, Penna. Co., Pittsburg, Pa.

Date of Membership.		
Feb. 4, '88.	Estrade, E. D.,	Engineer, Chief Eng. Office, P., C. & St. L. Ry., Pittsburg, Pa.
Nov. 15, '87.	Euwer, A. H.,	Lumber Merchant, Allegheny, Pa.
Mar. 6, '86.	Ferris, Geo. W. G.,	C.E., Insp. of Iron and Steel, P. O. Box 539, Pittsburg, Pa.
Apr. 19, '87.	Fielding, J. S. C. E.,	Peterborough, Ont.
Jan. 20, '85.	Fitler, F. K.,	121 Water St., Pittsburg, Pa.
Apr. 16, '89.	Fleming, H. S.,	1409 Walnut St., Philadelphia, Pa.
Jan. 18, '87.	Follansbee, Gilbert,	Supt. Chamber of Commerce, Pittsburg, Pa.
Oct. 21, '90.	Foster, Jas.,	Care Jennings Bros. & Co., Pittsburg, Pa.
Feb. 21, '82.	Frank, Isaac W.,	Founder, Lewis Foundry Co. Pittsburg, Pa.
Jan. 6, '80.	Frost, A. E.,	Prof. of Physics, W. U., Perryville Ave., Allegheny, Pa.
Apr. 17, '88.	Fulton, Louis B.,	Chancery Lane, Pittsburg, Pa.
Jan. 19, '86.	Geisenheimer, W. A.,	608 Fifth Ave., Pittsburg, Pa.
Apr. 15, '90.	Giles, W. A.,	Schmidt Bldg., Pittsburg, Pa.
Oct. 16, '83.	Glafey, Frederick,	Keystone Bridge Works, Pittsburg, Pa.
Feb. 17, '80.	Goodyear, S. W.,	Waterbury, Conn.
Jan. 21, '90.	Goodwin, J. M.,	Sharpsville, Mercer Co., Pa.
Jan. 6, '80.	Gotleib, A.,	Room 75, Major's Block, Chicago, Ill.
June 16, '85.	Grant, Horace E.,	119 First Ave., Pittsburg, Pa.
Apr. 21, '85.	Griffen, A. L.,	Keystone Bridge Co., Pittsburg, Pa.
Sept. 19, '82.	Gwinner, Fred., Jr.,	Contractor, Allegheny, Pa.

Date of Membership.		
Mar. 20, '83.	Hackett, Geo. W.,	Cement, Lime and Terra Cotta, 1009 Library St., Pittsburg, Pa.
Dec. 16, '90.	Hall, Chas. M.,	95 Fifth Ave., Pittsburg, Pa.
May 17, '80.	Hammer, Hakon,	4605 Fifth Ave., Pittsburg, Pa.
Oct. 15, '89.	Handy, J. O.,	95 Fifth Ave., Pittsburg, Pa.
Feb. 17, '91.	Hardie, J. B.,	Keystone Bridge Co., Pittsburg, Pa.
Jan. 6, '80.	Harlow, Jas. H.,	Hydraulic Engineer, 411 Wood St., Pittsburg, Pa.
Apr. 19, '81.	Harlow, Geo. R.,	Hydraulic Engineer, 441 Wood St., Pittsburg, Pa.
Jan. 6, '80.	Hemphill, Jas.,	Machinist, Mackintosh, Hemphill & Co., Pittsburg, Pa.
Nov. 14, '85.	Heron, Fred.,	Supt. Phœnix Iron Works, Phœnixville, Pa.
Jan. 19, '86.	Hetzel, Jas.,	60 Fourth Ave., Pittsburg, Pa.
Apr. 19, '87.	Hibbard, H. D.,	Care Dr. Litchfield, Neville St., E. E., Pittsburg, Pa.
Feb. 17, '91.	Hicks, Geo. J.,	Room 509, Lewis Bldg., Pittsburg, Pa.
Nov. 20, '88.	Hoag, I. V., Jr.,	43 Sixth Ave., Pittsburg, Pa.
Apr. 20, '80.	Hoffstot, Frank N.,	Iron Broker, Water St., Pittsburg, Pa.
Sept. 18, '88.	Hohl, L. I.,	Ruth St., 32d Ward, Pittsburg, Pa.
Dec. 18, '88.	Holland, W. J.,	Fifth Ave., Oakland, Pittsburg, Pa.
Nov. 15, '87.	Hopke, T. M.,	Linden Steel Co., Pittsburg, Pa.
Oct. 16, '88.	Howe, H. M.,	287 Marlboro St., Boston, Mass.

Date of Membership.		
Oct. 18, '81.	Hunt, A. E.,	Chemist, Schmidt & Friday Bldg., Pittsburg, Pa.
Jan. 22, '89.	Hunt, H. E.,	Emerson St., E. E., Pittsburg, Pa.
Oct. 21, '90.	Hutchinson, G. H.,	Keystone Bridge Co., Pittsburg, Pa.
Oct. 18, '87.	Hyde, C.,	Eng., Room 23, Lewis Bl'k, Pittsburg, Pa.
Mar. 18, '80.	Jarboe, W. S.,	14 Garfield Ave., Allegheny, Pa.
Dec. 18, '88.	Jenkins, J. B.,	98 Arch St., Allegheny, Pa.
Feb. 22, '81.	Jennings, B. F.,	Preble Ave, Allegheny, Pa.
Jan. 18, '88.	Johnson, Thos. H.,	Penna. Lines, Tenth and Penn Sts., Pittsburg, Pa.
Apr. 19, '81.	Jones, B. F.,	Iron Manufacturer, Pittsburg, Pa.
Mar. 20, '88.	Jones, W. Larimer,	Jones & Laughlins, Ltd., Pittsburg, Pa.
Nov. 16, '80.	Kaufman, Gustave,	814 Hamilton Building, Pittsburg, Pa.
May 16, '80.	Kay, J. C.,	Machinery, Kay Bros. & Co. Water St., Pittsburg, Pa.
Feb. 17, '85.	Kay, Jas. I.,	Patent Attorney, 96 Diamond St., Pittsburg, Pa.
June 19, '88.	Keating, A. J.,	Iron Mfr., Zug & Co., Pittsburg, Pa.
May 21, '89.	Keenan, J. J.,	Hollidaysburg, Blair Co., Pa.
Mar. 17, '85.	Kelly, J. A.,	28th and Smallman Sts., Pittsburg, Pa.
Jan. 16, '85.	Kelly, J. W.,	Box 196, New Brighton, Beaver Co., Pa.
Feb. 17, '91.	Kemler, W. H.,	1823 Carson St., Pittsburg, Pa.

Date of Membership.		
May 18, '86.	Kennedy, Julien,	Latrobe, Pa.
Sept. 19, '82.	Kenyon, L. H.,	Pitts. Locomotive Works, Allegheny, Pa.
Mar. 19, '89.	Kerr, A. C.,	Third Ave., Pittsburg, Pa.
Mar. 18, '90.	Kerr, C. V.,	42 Clifton Park, Allegheny, Pa.
June 19, '88.	Kimball, Frank I.,	Mining Engineer, Greensburg, Pa.
Feb. 21, '82.	King, T. M.,	B. & O. R.R., Baltimore, Md.
Mar. 16, '82.	Kirk, Arthur,	Arthur Kirk & Son, Powder and High Explosives, 910 Duquesne Way, Pittsburg, Pa.
Nov. 15, '87.	Kirtland, A. P.,	Acmetonia, Pa.
Apr. 19, '87.	Klages, Geo. W.,	Machinist, Foreman, 130 Eleventh St., S. S., Pittsburg, Pa.
Apr. 19, '87.	Koch, Walter E.,	Supt. Spang's Steel Works, Sharpsburg, Pa.
Jan. 6, '80.	Laing, Geo.,	1004 Penn Ave., Pittsburg, Pa.
Nov. 20, '88.	Langley, J. W.,	136 First Ave., Pittsburg, Pa.
May 19, '85.	Lauder, Geo.,	48 Fifth Ave., Pittsburg, Pa.
June 19, '88.	Lean, D. R.,	Lean & Blair, Engineers and Contractors, Pittsburg, Pa.
Jan. 17, '88.	Leech, Louis D.,	44th St. and Centre Ave., Pittsburg, Pa.
Apr. 15, '84.	Leishman, John A. G.,	Lewis Block, Pittsburg, Pa.
May 16, '80.	Leschorn, Alex.,	M. E., Phœnix Bridge Co., Phœnixville, Pa.
Mar. 16, '80.	Lewis, J. L.,	Lewis Foundry and Machine Co., Ltd., Pittsburg, Pa.
Apr. 20, '80.	Lewis, W. J.,	Linden Steel Co., Pittsburg, Pa.

Date of Membership.		
May 20, '90.	Lewis, H. J.,	Keystone Bridge Co., Pittsburg, Pa.
Feb. 21, '82.	Lindenthal, Gustave,	Engineer, Lewis Block, Pittsburg, Pa.
Oct. 16, '88.	Linkenheimer, A. E.,	141 Federal St., Allegheny.
Sept. 16, '84.	Lloyd, Henry,	Iron Mfr., H. Lloyd, Sons & Co., Pittsburg, Pa.
May 19, '81.	Lloyd, John W.,	Iron Mfr., H. Lloyd, Sons & Co., Pittsburg, Pa.
Nov. 18, '90.	Lobingier, J. E.,	Braddock, Pa.
Oct. 19, '80.	Loomis, Geo. P.,	Iron Mfr., Crescent Steel Works, Pittsburg, Pa.
Sept. 16, '90.	Ludwig, Jos.,	43 Marion St., Pittsburg, Pa.
Jan. 6, '80.	Macbeth, Geo. A.,	Keystone Flint Glass Co., Pittsburg, Pa.
Apr. 19, '81.	Malone, M. L.,	Engineer, 320 Fifth Ave., Pittsburg, Pa.
Jan. 6, '80.	Martin, Wm.,	Resident Eng., Davis Island Dam., P. O. Box 70, Pittsburg, Pa.
Dec. 18, '83.	Mead, Edwd.,	P. O. Box 124, Louisville, Ky.
Feb. 17, '91.	Means, E. C.,	Westinghouse Electric Co., Pittsburg, Pa.
June 18, '89.	Mellor, Walter C.,	77 Fifth Ave., Pittsburg, Pa.
Sept. 16, '90.	Mercàder, Camille,	Edgar Thompson St'l Wks., Braddock, Pa.
Mar. 20, '88.	Mesta, Geo.,	Leechburg Foundry and Machine Co., Leechburg, Pa.
Jan. 6, '80.	Metcalf, Wm.,	Crescent Steel Works, 49th and R. R. Sts., Pittsburg, Pa.
Jan. 15, '84.	Meyran, L. A.,	Canonsburg Iron and Steel Co., Germania Bank Bldg., Pittsburg, Pa.

Date of Membership.		
Sept. 18, '83.	Miles, Geo. K.,	Sec. and Treas. Charlotte Fur Co., Pittsburg, Pa.
Feb. 21, '82.	Milholland, J. B.,	Engine Builder, Fifth Ave., Pittsburg, Pa.
Jan. 6, '80.	Miller, Reuben,	Crescent Steel Works, Pittsburg, Pa.
May 19, '85.	Miller, Wilson,	Sec. Pittsburg Loco. Works, 18 Lincoln Ave., Allegheny, Pa.
Oct. 19, '80.	Milliken, A. C.,	Pottsville Iron and Steel Co. Pottsville, Pa.
Apr. 19, '81.	Moorhead, M. K.,	Moorhead-McClean Co., Pittsburg, Pa.
Mar. 15, '81.	Morgan, Jas.,	2204 Carson St., Pittsburg, Pa.
Apr. 15, '90.	Morgan, Wm.,	2 Sixth St., Pittsburg, Pa.
Oct. 19, '86.	Morris, G. W.,	P. O. Box 56, Pittsburg, Pa.
Jan. 21, '90.	Morris, H. Saunders,	Westinghouse Electric Co., Pittsburg, Pa.
May 15, '83.	Morse, H. C.,	Engineer, Edgemoor, Del.
Mar. 18, '90.	Mueller, Gustave,	78 Second St., Allegheny, Pa.
Apr. 15, '80.	Munro, R.,	Boiler Manufacturer, 23d and Smallman Sts., Pittsburg, Pa.
Mar. 16, '80.	McCandless, E.. V,	Merchant, Pittsburg, Pa.
Jan. 20, '91.	McClintock, H.,	Plummer, McClintock & Irvine, S. Ave. and Snowden St., Allegheny, Pa.
May 19, '85.	McConnell, John A.,	69 Water St., Pittsburg, Pa.
Mar. 15, '81.	McCulley, R. L.,	101 Fifth Ave., Pittsburg, Pa.
Feb. 22, '81.	McCune, John D.,	98 Fourth Ave., Pittsburg, Pa.
May 21, '89.	McDonald, John,	239 Forty-fourth St., Pittsburg, Pa.
Dec. 17, '89.	McDonald, C. J.,	314 Penn Building, Pittsburg, Pa.

Date of Membership.		
Apr. 18, '87.	McDowell, James,	Optician, Observatory Ave., Allegheny, Pa.
Oct. 21, '90.	McFarland, N. J.,	Care Jennings Bros. & Co., Pittsburg, Pa.
Dec. 16, '90.	McIntyre, J. B.,	131 Urania Ave., Greensburg, Pa.
Jan. 20, '91.	McKaig, Thos. B.,	95 Fifth Ave., Pittsburg, Pa.
Sept. 21, '80.	McKinney, J. P.,	60 Sheffield St., Allegheny, Pa.
Jan. 16, '83.	McKinney, R. M.,	Elizabeth, Pa.
Mar. 15, '81.	McLennan, Alex.,	56 Sec'nd Ave., Pittsburg, Pa.
Feb. 21, '82.	McMurtry, Geo. G.,	Pittsburg, Pa.
Feb. 17, '85.	McQuiston, Jas.,	26th and Railroad Sts., Pittsburg, Pa.
Mar. 15, '81.	McRoberts, J. H.,	400 Grant St., Pittsburg, Pa.
Apr. 15, '84.	McTighe, Jas. J.,	175 W. Carson St., S. S., Pittsburg, Pa.
Jan. 6, '80.	Naegley, John,	Eng. and Architect, Room 9, Renshaw Bldg., Liberty & 9th Sts., Pittsburg, Pa.
Jan. 19, '86.	Nevins, Richard, Jr.	Seattle, Washington.
	Nichols, T. B.,	223 Allegheny Ave., Allegheny, Pa.
Apr. 20, '80.	Nimick, F. B.,	Steel Mfr., Singer, Nimick & Co., Pittsburg, Pa.
Feb. 21, '82.	Noble, Patrick,	Pacific R. M. Co., 202 Market St., San Francisco, Cal.
Feb. 20, '83.	Paddock, Jos. H.,	Civil Engineer, Connellsville, Pa.
Nov. 18, '90.	Page, Benj.,	Monon. Con. R. R., 3d Ave. and Try St., Pittsburg, Pa.
May 21, '89.	Paine, G. H.,	Swissville, Pa.
Mar. 18, '84.	Painter, Park,	Iron Mfr., J. Painter & Sons, Pittsburg, Pa.

Date of Membership.		
Nov. 20, '88.	Palmer, W. P.,	37 Beach St., Allegheny, Pa.
Sept. 18, '88.	Park, J. G.,	Room 90, Westinghouse Bldg., Pittsburg, Pa.
Jan. 6, '80.	Parkin, Chas.,	Parnassus, Pa.
Apr. 15, '84.	Parkin, Walter F.,	136 First Ave., Pittsburg, Pa.
Feb. 22, '81.	Patterson, Peter,	National Tube Works, McKeesport, Pa.
Nov. 15, '81.	Paul, J. W.,	Verona Tool W'ks, Seventh Ave. and Liberty St., Pittsburg, Pa.
Apr. 15, '84.	Paulson, Frank G.,	Hatter, Wood St., Pittsburg, Pa.
Mar. 15, '87.	Pease, Chas. T.,	Westinghouse Electric Co., Pittsburg, Pa.
Sept. 18, '83.	Peebles, Andrew,	Architect, Schmidt & Friday Building, Pittsburg, Pa.
Jan. 6, '81.	Pettit, Robt. E.,	Penna. R. R. Co., Altoona, Pa.
Jan. 20, '80.	Phillips, F. C.,	Prof. of Chemistry, 59 Sherman Ave., Allegheny, Pa.
Jan. 16, '83.	Phipps, Henry, Jr.,	Carnegie, Phipps & Co., Ltd., Pittsburg, Pa.
Dec. 20, '81.	Porter, John C.,	Spang Steel and Iron Co., Pittsburg, Pa.
May 17, '87.	Porter, John E.,	Iron Broker, Penn and Second Sts., Pittsburg, Pa.
Jan. 16, '83.	Prentice, W. J.,	Cement, Lime & Terra Cotta, 1009 Liberty St., Pittsburg, Pa.
Apr. 17, '83.	Price, C. B.,	A. V. R. R., Pittsburg, Pa.
Dec. 18, '88.	Purves, Jas.,	Munhall, Pa.
Jan. 6, '80.	Quincy, W. C.,	Mon. Cen. R. R., 3d Ave. and Try St., Pittsburg, Pa.
Mar. 15, '81.	Ramsey, Jos., Jr.,	Asst. V.-Pres. C. C. C. I. & St. L. Ry., Cincinnati, O.

Date of Membership.		
Dec. 16, '90.	Randolf, Alfred,	53 Carson St., Pittsburg, Pa.
Jan. 20, '80.	Reed, Jas.,	Supt. W. Penn. Div. P. R.R. Allegheny, Pa.
Dec. 17, '89.	Reed, J. R.,	150 Fayette St., Allegheny, Pa.
Jan. 20, '80.	Rees, Thos. M.,	Machinist, J. Rees & Sons, Pittsburg, Pa.
June 19, '88.	Reinmann, A. L.,	Westinghouse Electric Co., Pittsburg, Pa.
May 15, '83.	Reno, Geo. E.,	90 Fourth Ave., Pittsburg, Pa.
Jan. 9, '80.	Rhodes, Joshua,	Penna. Tube Works, Pittsburg, Pa.
Jan. 6, '80.	Ricketson, John H.,	Founder, 6 Wood St., Pittsburg, Pa.
Apr. 19, '87.	Rider, Percy S.,	6 Ninth St., Pittsburg, Pa.
Apr. 15, '90.	Ritchie, Jas.,	7th Avenue Hotel, Pittsburg, Pa.
Jan. 17, '88.	Robbins, F. L.,	Penn Bldg., Pittsburg, Pa.
Jan. 7, '80.	Roberts, Thos. P.,	C. Engineer, 53 Beach St., Allegheny, Pa.
Jan. 7, '80.	Rodd, Thos.,	Penna. Co., Pittsburg, Pa.
Nov. 19, '89.	Ruhe, C. H. Williams,	102 Bluff St., Pittsburg, Pa.
Jan. 17, '88.	Ruud, Edwin,	706 Penn Ave., Pittsburg, Pa.
Apr. 15, '84.	Scaife, O. P.,	Wm. B. Scaife & Sons, Structural Iron Works, 119 First Ave., Pittsburg, Pa.
Mar. 20, 83.	Scaife, W. Lucien,	Scaife Foundry & Machine Co., Twenty-Eighth and Smallman Sts., Pittsburg, Pa.
Sept. 20, '87.	Scaife, W. Marcelin,	336 Ridge Ave., Allegheny, Pa.
Apr. 15, '90.	Scheffler, Fred. A.,	Westinghouse Electric Co., Pittsburg, Pa.

Date of Membership.		
Feb. 21, '82.	Schellenberg, F. Z.,	Elysian St., E. E., Pittsburg, Pa.
Jan. 6, '80.	Schinneller, Jacob,	M.E., Room 31, McClintock Block, Pittsburg, Pa.
Feb. 17, '85.	Schmid, Alb.,	Supt. Westinghouse Electric Co., Pittsburg, Pa.
May 15, '83.	Schook, Levi,	First Ave and Ferry Sts., Pittsburg, Pa.
Jan. 6, '80.	Schultz, A. L.,	Hiland Ave., E. E., Pittsburg, Pa.
Sept. 19, '82.	Schultz, C. J.,	Iron City Bridge Works, Pittsburg, Pa.
Nov. 15, '81.	Schwartz, F. H.,	5000 Liberty St., Pittsburg, Pa.
Mar. 18, '84.	Schwartz, J. E.,	61 Fourth Ave., Pittsburg, Pa.
Apr. 15, '90.	Scott, Chas. F.,	Westinghouse Electric Co., Pittsburg, Pa.
Feb. 17, '91.	Scott, E. K.,	Keystone Bridge Co., Pittsburg, Pa.
Sept. 16, '90.	Scott, J. B.,	122 Second Ave., Pittsburg, Pa.
Jan. 16, '83.	Seaver, J. W.,	79 Fremont St., Allegheny, Pa.
Jan. 22, '89.	Shaw, A. G.,	5268 Carnegie St., Pittsburg, Pa.
Jan. 22, '89.	Shaw, W. W.,	County Engineer's Office, Pittsburg, Pa.
Sept. 19, '82.	Sherzer, W.,	C. E., 209 Home Insurance Building, Chicago, Ill.
Nov. 24, '85.	Shultz, O. G.,	McKee's Rocks P. O., Pa.
Dec. 29, '87,	Simpson, Jas. H.,	Carnegie, Phipps & Co., Ltd. Pittsburg, Pa.
Sept. 21, '80.	Singer, Harton G.,	83 Water St., Pittsburg, Pa.
May 20, '90.	Singer, R. R.,	111 Fourth Ave., Pittsburg, Pa.

Date of Membership.		
Sept. 21, '80.	Singer, W. H.,	Singer, Nimick & Co.. Pittsburg, Pa.
Jan. 6, '80.	Slataper, Felician,	Chief Eng. Penna. Co., Pittsburg, Pa.
Jan. 21, '90.	Smith, F. S.,	Westinghouse Electric Co., Pittsburg, Pa.
Feb. 17, '80.	Snyder, Antes,	Eng. Right of Way, P.R.R., Blairsville, Pa.
Apr. 15, '84.	Snyder, W. P.,	Lewis Block, Pittsburg, Pa.
Jan. 18, '88.	Speer, B.,	Prof. of Physics, Pitts. High School, Pittsburg, Pa.
Feb. 17, '80.	Sprague, H. N.,	Porter & Co., Loco. Works, Pittsburg, Pa.
May 19, '81.	Stafford, C. E.,	Shoenberger & Co., Pittsburg, Pa.
May 19, '83.	Stevenson, David A.,	Civil Engineer, Room 6, Union Station, Pittsburg, Pa.
Jan. 19, '86.	Stevenson, W. S.,	Fairmount, W. Va.
Nov. 21, '82.	Stewart, Geo. R.,	Gas Engineer,, 43 Sixth Ave. Pittsburg, Pa.
Oct. 19, '86.	Stewart, J. H.,	Care F. F. Vandevort & Co., Lewis Blk., Pittsburg, Pa.
Jan. 6, '80.	Stillburg, J. H.,	Architect, 20 Fifth Ave., Pittsburg, Pa.
Jan. 21, '90.	Stillwell, L. B.,	Westinghouse Electric Co., Pittsburg, Pa.
Oct. 21, '90.	Stowe, H. C.,	Room 801 Penn Bldg., Pittsburg, Pa.
Jan. 6, '80.	Strobel, C. L.,	M. E., 205 LaSalle St., Chicago, Ill.
Feb. 17, '91.	Stupakoff, S. H.,	Union Switch and Signal Co., Swissvale, Pa.
Feb. 20, '83.	Swan, Robert,	Civil Eng., Allegheny Ave., Allegheny, Pa.
Apr. 19, '87.	Swenson, Emil,	Keystone Bridge Works, Pittsburg, Pa.

Date of Membership.		
Feb. 19, '84.	Taylor, B. H.,	C. E., Edgar Thompson Stl. Works, Braddock, Pa.
Apr. 20, '80.	Taylor, E. B.,	Genl. Supt. Penna Co., Pittsburg, Pa.
Dec. 16, '90.	Temple, W. C.,	408 Lewis Block, Pittsburg, Pa.
May 18, '86.	Tener, Geo. E.,	Oliver Bros. & Phillips, New Castle, Pa.
Dec. 21, '81.	Thaw, Wm., Jr.,	Hecla Coke Co., 21 Lincoln Ave., Allegheny, Pa.
Apr. 19, '89.	Thorsell, J. A.,	119 First Ave., Pittsburg, Pa.
Apr. 9, '91.	Tibbitt, C. H.,	68 Sixth Ave., Pittsburg, Pa.
Mar. 18, '91.	Tone, S. L.,	19 Jackson Building, Pittsburg, Pa.
Dec. 16, '90.	Tonnelé, Theo.,	McKeesport, Pa.
Jan. 6, '80.	Trimble, Robt.,	Penna. Co., Pittsburg, Pa.
Feb. 22, '81.	Utley, Edwd. H.,	A. V. R. R., Pittsburg, Pa.
May 19, '85.	Verner, M. S.,	Supt. Citizens' Traction Co., 939 Penn Ave., Pittsburg, Pa.
Dec. 20, '87.	Verner, Henry W.,	8 Wood St., Pittsburg, Pa.
Apr. 18, '82.	Wainwright, J.,	C. E., 111 Fourth Ave., Pittsburg, Pa.
Apr. 19, '87.	Wainwright, J. R.,	P. O. Box 264, Pittsburg, Pa.
Jan. 6, '80.	Walker, J. W.,	Forty-seventh St. and A. V. R. R., Pittsburg, Pa.
Jan. 16, '83.	Warden, C. F.,	
Jan. 6, '80.	Weeks, Jos. D.,	Editor Amer. Manufacturer, Box 1547, Pittsburg, Pa.
Apr. 19, '87.	Weiskopf, Saml. C.,	Box 732, Pittsburg, Pa.
Feb. 21, '82.	Westerman, Thos.,	Verona Tool Works, Verona, Pa
Feb. 20, '88.	White, H.,	21 Church Ave., Allegheny, Pa.
May 15, '83.	White, T. S.,	Penna. Bridge Works, Beaver Falls, Pa.

Date of Membership.		
May 18, '80.	Wickersham, S. M.,	C. Eng., Home St., Allegheny, Pa.
Oct. 19, '80.	Wickersham, Thos.,	Mill Mgr., Park Bros. & Co., Pittsburg, Pa.
Oct. 21, '90.	Wieland, C. F.,	Care Riter & Conley, Allegheny, Pa.
May 18, '86.	Wierman, Victor,	Eng. Pgh. Div. P. R. R., Pittsburg, Pa.
Jan. 21, '90.	Wigham, Wm.,	Camden, Pa.
Feb. 17, '80.	Wightman, D. A.,	Supt. Pittsburg Loco. Works, Box 76, Allegheny, Pa.
Jan. 6, '80.	Wilcox, John F.,	J. P. Witherow, Lewis Block, Pittsburg, Pa.
May 15, '87.	Wilkins, W. G.,	C. E., 244 Western Ave., Allegheny, Pa.
Jan. 19, '86.	Wilson, Howard M.,	Founder, Craig St., Pittsburg, Pa.
Jan. 18, '88.	Wilson, F. T.,	Jersey Shore, Lycoming Co., Pa.
Jan. 18, '88.	Wilson, W. R.,	811 Penn Building, Pittsburg, Pa.
Feb. 20, '88.	Winn, Isaac,	National Rolling Mill, McKeesport, Pa.
Jan. 6, '80.	Witherow, J. P.,	Eng. and Contractor, Lewis Block, Pittsburg, Pa.
Nov. 19, '89.	Wolffe, J. J. E.,	Keystone Bridge Co., Pittsburg, Pa.
Jan. 15, '84.	Wood, B. L., Jr.,	Mon. Dredging Co., 43 Sixth Ave., Pittsburg, Pa.
Sept. 21, '80.	Wood, R. G.,	Iron Mills, McKeesport, Pa.
Jan. 18, '88.	Wood, Jos.,	Genl. Supt. Transportation Pa. Lines, Pittsburg, Pa.
Jan. 18, '88.	Woods, Leonard G.,	East End Hotel, Pittsburg, Pa.
Jan. 6, '80.	Zimmerman, W. F.,	U. S. Electric Co., Newark, N. J.

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Tichnischer Verein, 210 E. Fifth St., New York.
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Journal of Society of Arts, John St., Adelphi, London, W. C.
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